UM3401

User manual

Teseo VI and Teseo APP2–RTCM3 proprietary interface

Introduction

This specification describes the RTCM3 proprietary protocol interface of Teseo VI and Teseo APP2.

Note: Some of the features described in this document could be “not yet supported” by the current firmware release. A separate release notes document is provided for each new firmware, detailing the status of the development.

1 Overview

Teseo VI and Teseo APP2 devices embed the Arm® Cortex®-M7.

For information on the Arm® Cortex®-M7, refer to the technical reference manuals, available from the www.arm.com website.

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Teseo VI is a GNSS multifrequency measurement engine. It outputs all the GNSS measurements and navigation data needed to drive a precise positioning navigation algorithm, located on a host processor. A single-band PVT solution is also autonomously computed for monitoring and integrity purposes. Other supported features include: timing and PPS generation, autonomous acquisition in COLD conditions, measurement epoch generation and steering, navigation data decoding and storage on external NVM. Assistance at startup is supported in the form of time/position aiding and real-time ephemeris/almanacs upload.

1.1 Frequency plan

The constellation mask is a 32-bit integer mask, where each enabling bit indicates if the corresponding satellite system or signals must be supported (1 = yes, 0 = no), as from a firmware configuration document CDB [P21,L04].

The multi-frequency mask is a 32-bit integer mask, where each bit indicates if the corresponding frequency signal has enabled some multi-frequency, pilot/data and tracking mode (see a firmware configuration document [P21,L05], refer to Appendix B: Acronyms and reference documents).

Starting from the configured constellation mask and multi-frequency mask, the receiver firmware automatically selects a scenario.

2 GNSS metrics

2.1 GNSS metrics description

The reported GNSS metrics are described in the following table.

Table 1. GNSS metrics

Name	Description
SQM	The signal quality metrics are calculated using the direct output of the tracking loops (for example, loop discriminators).
ACM	The autocorrelation metric reports the correlation shape with the help of additional monitoring tracking channels, for the detection of spoofing signals, strong multipath and other signal impairments, affecting the shape of the correlation peak.
OBSQM	The observable quality metrics report the output of the measurement engine, performed on the observables (for example, pseudorange, carrier-phase, Doppler, CN0 etc.).
IFB	Inter-frequency bias estimates the inter-frequency bias, cross-checking with the predefined, stored values (for example, either from initial/factory calibration or directly provided by the host at start-up).

2.1.1 Signal quality metrics (SQM)

Signal quality metrics are detected during normal tracking with the goal of reporting deviations of the signal parameters from nominal values. Loss of lock due to CN0 or bad timing alignment, instead, is detected by other control paths, which cause signal reacquisition.

SQM are calculated from the channels in normal tracking state and are based on signal quality metrics from the carrier and code loops and from the combination of up to 5x I-Q correlation points.

The following signal quality metrics are collected:

- CN0 carrier to noise density estimate
- Multipath metric, based on powers at 5x correlation points:

$$\hat{s}_{MP} = \frac{(P_{VE} - P_{VL}) - (P_E - P_L)}{P_P} \quad (1)$$

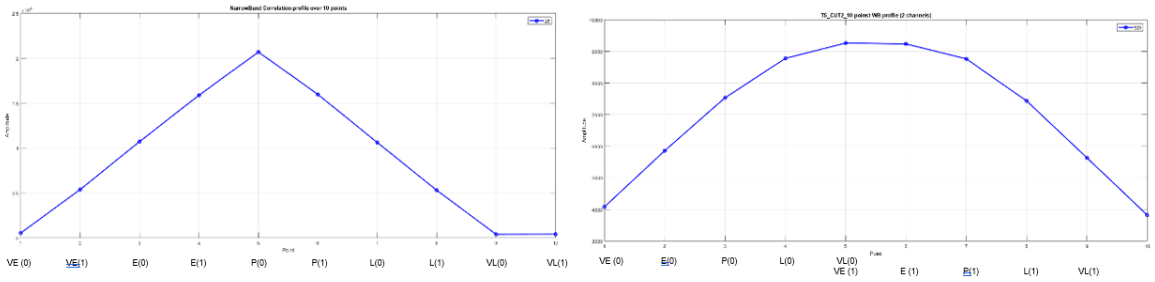
- Carrier loop discriminator output standard deviation estimate
- Reference code loop discriminator (E-L) output bias estimate

2.1.2 Auto-correlation metric (ACM)

ACM can be used to detect spoofing attacks, heavy multipath and other signal impairments. A set of dedicated monitoring channels analyze all the active tracking channels, providing additional multi-correlation capability.

The multi-correlation shapes derived by the monitoring channels include 10x correlation points. For a typical narrow-band (GPS L1) and wide-band (Galileo L5) signals, these shapes are illustrated in the following figure.

Figure 1. Multi-correlation shapes, narrow-band (left) and wide-band (right)



From the accumulated power at the 10x correlation points, the signal quality metric is computed by summing the power unbalances.

Narrow band ACM:

$$ddm_{EXT} = \frac{(VE(0) - VL(0)) + (E(0) - L(0)) + (VE(1) - L(1)) + (E(1) - P(1))}{P(0)} \quad (2)$$

Wide band ACM:

$$ddm_{EXT} = \frac{(VE(0) - VL(1)) + (E(0) - L(1)) + (P(0) - P(1)) + (L(0) - E(1))}{\left(\frac{(VL(0) + VE(1))}{2}\right)} \quad (3)$$

2.1.3 Observable quality metrics (OBSQM)

This class of metrics is gotten from the observables produced by the measurement engine. The following observable quality metrics are computed:

Code minus carrier combination

$$ccdt = \frac{z_k - z_{k-1}}{dt} \quad (4)$$

Code-rate doppler combination

$$crd = D_k + \frac{\rho_k - \rho_{k-1}}{\lambda_n \cdot dt} D_k = f_k - f_{CK}\frac{Ln}{L1} \quad (5)$$

Dual-frequency carrier-phase difference

$$cpdt = \frac{\Delta\phi_k - \Delta\phi_{k-1}}{dt} \Delta\phi_k = \lambda_1 \phi_{1,k} - \lambda_n \phi_{n,k} \quad (6)$$

Dual-frequency pseudorange difference

$$psrd = (\rho_1) - (\rho_2 - \gamma i_2) mod 1ms \quad (7)$$

Where:

- k = measurement epoch index
- n = carrier frequency index (1 = L1, 2 = L2, 5 = L5, etc.)
- Ln = carrier center frequency [Hz]
- ρ_n = pseudo-range observable [m]
- i_n = ionosphere delay (from model)
- $\Phi_{n,k}$ = carrier-phase observable [cycles]
- f = frequency observable [Hz]
- λ_n = carrier wavelength [m]
- t(k) = measurement epoch time [s]
- f_{CK} = receiver clock drift on L1 [Hz]

2.1.4 Inter-frequency bias (IFB)

The measurement engine shall compensate for inter-frequency biases (for example, L1-L2) in the pseudorange. The compensation biases shall be considered as constant values, configurable by the host at start-up. The PSR and ADR rates are also estimated and compared to a programmable, constant, upper bound. These biases are continuously reported by Teseo VI and they can be checked against the programmed values.

2.1.5 GNSS information

Throughout the production of the GNSS information, the Teseo GNSS configured as measurement engine verifies their validity and it decides whether to send the information or not to the HOST. The following table summarizes the type of exclusion performed, based on the GNSS information, how the HOST can verify if the filtering has been performed and if the information received can be used.

Table 2. GNSS information filtering

Information	Validity indicator	Exclusion type
Observables channel	No indication–internal channel filtering	Channel observable exclusion
Observables channel	RTCM/SIGQM2 dsp.flags bit 23 (preamble_prop)	Channel observable sent to host–usage not recommended
Observables channel	RTCM/SIGQM2 dsp.flags cp_int and psr_int	Channel observable sent to host–usage not recommended
Observables constellation	RTCM/IFBDATA message, constellation alarm mask	Channel observable sent to host–usage not recommended
System time	RTCM/RSS message, time validity parameter	Channel observable sent to host–usage not recommended
Timing/PPS	RTCM/RSS message, timing/PPS status parameter	Hardware PPS signal is invalid, or system time correction not executed

2.1.6 Observable failure detection and exclusion (OFDE)

OFDE allows to detect and exclude observables based on the evaluation of signal and measurement metrics.

The value of each metric is compared to a threshold and, if it exceeds that threshold, the value of the integrity metric is increased for such satellite. The integrity metric is calculated for each signal, that is, for each tracked frequency of each available satellite.

Moreover, depending on which metric has exceeded the threshold, the carrier phase observable or all the observables (that is, pseudorange, carrier phase, doppler, and signal strength) are excluded from the RTCM3 measurements output (that is, MSM7 messages).

The Carrier to noise density estimation monitor (CN0), has configurable minimum thresholds (there are two thresholds: one for BeiDou GEO satellite, and another one for all remaining satellites), while the pseudoranges are checked against the fixed (non-configurable) minimum and maximum thresholds.

All the other metrics are compared to the corresponding variable configurable thresholds, which are functions of CN0, as expressed by the following formula:

$$thr\left(t, s, i\right) = \max\left(t, \frac{(((C_{N0thrs} - s) \cdot i) + I_{scale}) \cdot t}{I_{scale}}\right) \quad (8)$$

Where:

- *thr*: is the calculated threshold.
- *t*: is the base metric threshold (from firmware configuration CDB).
- *s*: is the current signal strength (CN0).
- *i*: is base metric inflating factor (from firmware configuration CDB).
- C_{N0thrs}: is the CN0 threshold from which the threshold should not increase anymore.
- I_{scale}: is the scale for the inflating factor.

Besides, the computed pseudoranges are compared against minimum and maximum thresholds' values.

In the case the following thresholds are exceeded, both the pseudorange and carrier phase integrity flags, reported in the DSP flags of each channel measurement on RTCM, are set:

- Code loop discriminator metric threshold
- Multipath metric threshold
- Autocorrelation metric threshold
- Carrier to noise density estimation monitor threshold
- Code minus carrier combination metric threshold
- Code-rate doppler combination metric threshold
- Pseudorange thresholds
- Satellite inter-frequency bias threshold

In case the following thresholds are exceeded, only the carrier-phase integrity flag in the DSP flags is set:

- Carrier loop discriminator metric threshold
- Dual-frequency carrier-phase difference threshold

The following table reports the metrics on which the OFDE is based, and which observables are excluded in case metrics exceed the indicated thresholds.

Table 3. OFDE metrics thresholds

Metrics	Default threshold	Default inflating value	Excluded observables
Carrier loop discriminator	4300	0.30	Carrier phase only
Code loop discriminator	1500	0.02	All
Double-delta metric (multipath metric, 5x)	1900	0.09	All
Auto-correlation metric (10x)	300	0.20	All
Code-carrier divergence	9000	0.16	All
Doppler–code rate divergence	49000	3.83	All
Dual-frequency carrier-phase delta gradient	32000	1.48	Carrier phase only (both 1st and 2nd frequency)
Inter-frequency bias (pseudorange)	20000	0.20	All
Pseudorange	Min: 15000000.0 Max: 49000000.0	-	All
Signal strength (CN0)	25 (30 for BDS GEO)	-	All

The metrics thresholds and inflating factors are encoded in the UM3428 (refer to Appendix B: Acronyms and reference documents) at CDB-ID [P37,L00-08] (refer to Section 2.1.6: Observable failure detection and exclusion (OFDE)). For the line #0-7 the threshold and inflating values are encoded on 32 bits: the least significant 16 bits (bit #0..15) encodes the thresholds divided by 16, while the most significant 16 bits (bit #16..31) encodes the inflating values multiplied by 100, as described in the following table. Both values are encoded as unsigned integers.

Table 4. Thresholds and inflating values in firmware configuration

Metrics	CBD line #	Default threshold	FW config value (/16) Bit #0..15	Default inflating value	FW config value (x100) Bit #16..31
Carrier loop discriminator	0	4300	268	0.30	30
Code loop discriminator	1	2000	125	0.03	3
Double-delta metric (multipath metric, 5x)	2	1900	118	0.09	9
Auto-correlation metric (10x)	3	300	18	0.20	20
Code-carrier divergence	4	9000	562	0.16	16
Doppler-code rate divergence	5	49000	3062	3.83	383
Dual-frequency carrier-phase delta gradient	6	32000	2000	1.48	148
Inter-frequency bias (pseudorange)	7	20000	1250	0.20	20

The signal strength (CN0) and signal strength (CN0) for BeiDou GEO are encoded in the [P37,L08], bit #0...7 and # 8...15 respectively, as 8-bit unsigned integers with no scaling factor.

Moreover, setting the whole line to 0xFFFFFFFF disables the check for the respective metric.

The dual-frequency carrier-phase delta gradient and inter-frequency bias (pseudorange) metrics are inter-frequency metrics, that is, they are calculated between the two tracked frequencies of the same satellite and are reported for both frequencies though. In case of anomalous value, it is not possible to understand which frequency has caused it.

The thresholds have been calculated from a 9-hour log of a Teseo VI receiver's metrics connected to a static roof antenna (static, roof antenna, GPS, L1 + L2C and L1+L5). For each metric, its stochastic distribution has been estimated form the samples collected in the log.

The average CN0 was 35.4 dBm for the 1st frequency and 33.0 dBm for the 2nd one.

The threshold values (excluded pseudorange metric) have been calculated as follows:

$$\boldsymbol{T_i} = \left(\|\boldsymbol{m_i}\| + 2\boldsymbol{\sigma_i}\right) \cdot \boldsymbol{I_i} \quad (9)$$

Where:

- T_i is the threshold value for the i-th metric
- m_i is the mean of the samples of the i-th metric
- σ_I is the standard deviation of the samples of the i-th metric
- I_i is the inflating factor for the i-th metric

Besides, an overall safety metric is computed based on the sum of metrics that exceeded the threshold for all the tracked satellites.

The OFDE thresholds and inflating values can be configured using the firmware configuration, by setting the threshold in the 16 less significant bits, and by setting the inflating value in the 16 most significant bits of the corresponding 32-bit configuration word of each metric.

3 Receiver operation

3.1 Tracking modes

The tracking modes supported are in the UM3428 (refer to Appendix B: Acronyms and reference documents) on CDB [P21,L04].

4 Host application protocol

The application layer host protocol is based on a mix of standard and proprietary RTCM3 message types.

Proprietary messages are defined by the proprietary message ID 4050 and each message is distinguished by a different subtype ID, in addition to the navigation data frame message, which can have the message ID equal to 4075.

The application layer host protocol is based on a mix of standard and proprietary RTCM3 message types.

Table 5. Standard RTCM3 messages

Msg. number	Description	Direction	Direction Teseo APP2 production FW
1077,1087, 1097,1117, 1127,1137	Multiple signal messages (MSM)	Out	Out
1019,1020, 1041,1042, 1044,1046	Satellite ephemeris data	In/Out	Out
1013	System parameters	Out	Out
1057, 1240 (Gal), 1258 (Bds)	SSR orbit correction	In/Out	NA
1058, 1241 (Gal), 1259 (Bds)	SSR clock correction	In/Out	NA
1059, 1242 (Gal), 1260 (Bds)	SSR satellite code bias	In/Out	NA
1060, 1243 (Gal), 1261 (Bds)	SSR combined orbit and clock correction	In	NA
4075	Navigation data frame (NDF) (1)	Out Teseo APP2: NA	NA

1. *Not in RTCM3 official standard*

Table 6. Proprietary RTCM3 messages

Msg. number	Subtype ID	Description	Direction	Direction Teseo APP2 production FW	Direction in field mode
4050	1	Receiver status and safety (RSS)	Out	Out	See previous columns
	2	Receiver configuration and control (RCC)	In/Out	Out	See previous columns
	3	Reserved	-	-	See previous columns
	4	Reserved	-	-	See previous columns
	5	Position quality metrics (POSQM)	Out	Out	See previous columns
	6	Observable quality metrics (OBSQM)	Out	Out	See previous columns
	7	GLONASS Inter-channel biases (ICB)	In/Out	Out	See previous columns
	8	Inter-frequency biases (IFB)	In/Out	Out	See previous columns
	9	Ionospheric model parameters (IONOPAR)	In/Out	Out	See previous columns
	10	Pulse per second (PPS)	In/Out	Out	See previous columns

Msg. number	Subtype ID	Description	Direction	Direction Teseo APP2 production FW	Direction in field mode
4050	11	GNSS prediction ephemeris (STGPE)	Out Teseo APP2 NA	NA	See previous columns
	12	Init time (INITTIME)	In Teseo APP2 NA	NA	See previous columns
	13	Almanac (ALMANAC)	In/Out Teseo APP2 Out	Out	See previous columns
	14	GNSS OSNMA (STNMA)	In/Out Teseo APP2 NA	NA	See previous columns
	15	Receiver suspend (SUSPEND)	In	In	See previous columns
	16	Receiver Restart (RESTART)	In	In	See previous columns
	17	Datum Reference (STDTM)	Out	Out	See previous columns
	18	Data retransmission request (TXREQ)	In	In	In stagps: 8passgen only
	19	Message response (RESP)	Out	Out	See previous columns
	20	Test message (TEST)	In	NA	NA
	21	Extended PVT (EPVT)	Out	Out	See previous columns
	22	Auxiliary data (AUX)	Out	Out	See previous columns
	23	Set message transmission Interval (SETMTI)	In	NA	See previous columns
	24	RF status (RFS)	Out	Out	See previous columns
	25	Firmware version (FWVER)	Out	Out	See previous columns
	26	Signal quality metrics 2 (SIGQM2)	Out	Out	See previous columns
	27	Inter-frequency bias data (IFBDATA)	Out	Out	See previous columns
	28	GNSS satellites In view (STGSV)	Out	Out	See previous columns
	29	GNSS DOP and active satellites (STGSA)	Out	Out	See previous columns
	30	GNSS pseudorange error Statistics (STGST)	Out	Out	See previous columns
	31	GNSS RAIM parameters (STGBS)	Out	Out	See previous columns
	32	GNSS range residuals (STGRS)	Out	Out	See previous columns
	34	AGPS message (STAGPS)(1)	Out Teseo APP2 NA	NA	See previous columns
	35	Debug Information message (STDBG)	Out	Out	See previous columns
	36	GNSS OSNMA event (STNMAEVT)	Out Teseo APP2 NA	NA	See previous columns
	37	OSNMA authenticated active satellites (STASA)	Out Teseo APP2 NA	NA	See previous columns
	38	OSNMA authenticated mInimum specific data (STAMC)	Out Teseo APP2 NA	NA	See previous columns
	39	Reserved	-	-	See previous columns
	40	Reserved	-	-	See previous columns
	41	Init position (INITPOS)	In Teseo APP2 NA	NA	See previous columns

Msg. number	Subtype ID	Description	Direction	Direction Teseo APP2 production FW	Direction in field mode
4050	42	Navigation data frame (NDF)	Out Teseo APP2 NA	NA	See previous columns
	43	RFAGC	Out	Out	See previous columns
	44	TG	Out Teseo APP2 NA	NA	See previous column
	64	Sensor message (SENS)	In/Out Teseo APP2 NA	NA	See previous columns

1. *Satellite ephemeris data at Input implements GNSS assistance.*

4.1 Message timing and scheduling

The messages are generated at the COM port. Observables are generated first to reduce PVT computation latency at the host side, followed by safety and integrity messages. Auxiliary data (for example ephemeris), when available, are sent last.

On Teseo APP2, the non-critical messages can be stopped at the end of epoch to avoid delay for the following epoch MSM7 messages. This message stop feature is configurable by CDB.

4.2 Data fields

The suffix ‘P’ identifies proprietary data fields vs. RTCM3 standard fields.

Table 7. Data fields

DF	DF name	DF range	DF Res.	Data type	Data field notes
DF002	Message number	0-4095	-	uint12	4050
DF003	Reference station ID	0-4095	-	uint12	Configured in CDB [P18, L13]
DF021	Reserved for ITRF realization year	-	-	uint6	-
DF054	Leap seconds, GPS-UTC	0-254 s	1 s	uint8	255 - the value is not provided
DF01P	Timing/PPS status	0-255	-	uint8	0 = ok 1...255 = do not use / not available
DF02P	Subtype ID	0-255	-	uint8	-
DF05P	Receiver clock counter	-	-	uint32	Nominal frequency F_0
DF06P	GNSS ID	0-15	-	uint4	0 = GPS 1 = GLONASS 2 = QZSS 3 = Galileo 4 = SBAS 5 = QZSS L1S 7 = BeiDou 10 = NavIC (IRNSS) 13 = BeiDou 6, 8, 9, 11, 12, 14, 15 = Reserved
DF07P	GNSS satellite mask	-	-	uint40	1-bit per sat. ID (MSB is the satellite #1) (for GNSS ID 13, MSB is the satellite #41 and bits 0-15 are RFU). See DF394 in RTCM3 standard document.

DF	DF name	DF range	DF Res.	Data type	Data field notes
					DF394 QZSS Satellite ID mask to PRN proprietary extension: 11 = PRN 203 (L1 C/B) 12 = PRN 204 (L1 C/B) 13 = PRN 205 (L1 C/B) 14 = PRN 206 (L1 C/B)
DF08P	Satellite geometric range	-	0.01 m	uint32	-
DF09P	Not used	-	-	-	-
DF10P	Signal CN0	0-255	0.25 dBHz	uint8	-
DF11P	Satellite elevation	0-255	0.5 deg	uint8	250..255 = special values
DF12P	Range accuracy	0-15	-	uint4	-
DF13P	Range-rate accuracy	0-15	-	uint4	-
DF14P	Receiver clock drift	-	-	-	-
DF15P	Epoch time fractional bias	-	-	-	-
DF16P	GNSS epoch time	-	1 ms	uint30	TOW for any GNSS
DF18P	Extended week number	-	1 week	uint16	Week number extended to 16-bit roll-over. The value FFFF is assumed as a not-valid week number
DF19P	Firmware version	-	-	uint24	-
DF20P	Monitors page mask	-	-	uint32	1-bit per monitor page (1=page follows, 0=no).
DF21P	Constellation alarm mask	-	-	uint32	Bit #0: GPS L1CA Bit #1: GLONASS G1 Bit #2: QZSS L1 CA Bit #3: Galileo E1 Bit #4: SBAS Bit #5: QZSS L1 SAIF Bit #6: QZSS L1C Bit #7: BeiDou B1I Bit #8: BeiDou B1C Bit #9: GPS L2C Bit #10:NavIC (IRNSS) L5 Bit #11: GPS L5 Bit #12: Galileo E5A Bit #13: Galileo E6 Bit #14: BeiDou B2A Bit #15: QZSS L2C Bit #16: QZSS L5 Bit #17: GPS L1C Bit #18: BeiDou B3I Bit #19: BeiDou B2B Bit #20: RFU Bit #21: GLONASS G2 Bit #22: BeiDou B2I Bit #23: Galileo E5B

DF	DF name	DF range	DF Res.	Data type	Data field notes
					Note: Bit #0 is the lsb
DF23P	Multiple message indicators	-	-	uint1	0 = last message of sequence 1 = multiple messages
DF24P	Integrity metrics value	-	-	uint32	Units and scaling are metrics dependent. The special value 0x7FFFFFFF means not valid or unknown. For pseudorange, carrier phase and doppler STD the special value 0xFFFFFFFF means saturation/not valid.
DF25P	Config. page number	-	-	uint8	Configuration and control page number
DF26P	Config. page mask	-	-	uint16	Configuration and control page mask, 1-bit set per config. word
DF27P	Config. words	-	-	uint32	Any configuration and control information field on 32-bit
DF28P	GPS quality indicator	-	-	uint4	As from NMEA $--GGA 0 = fix not available or invalid 1 = GPS, SPS mode, fix valid 2 = differential GPS, SPS mode, fix valid 6 = estimated (dead reckoning) mode
DF29P	Number of satellites in use	-	-	uint8	As from NMEA $--GGA
DF30P	Dilution of precision (DOP)	0-25.4	0.1	uint8	As from NMEA $--GGA
DF31P	Geoidal separation,centimeters	±163.83 m	0.01 m	int15	As from NMEA $--GGA
DF32P	Age of differentials	-	1 ms	uint24	As from NMEA $--GGA 0xFFFFFF = not valid
DF33P	Differential reference station ID	0-4095	-	uint12	Same DF003 format (from GGA)
DF34P	Antenna velocity ECEF-X	-	1E-6 m/s	int32	-
DF35P	Antenna velocity ECEF-Y	-	1E-6 m/s	int32	-
DF36P	Antenna velocity ECEF-Z	-	1E-6 m/s	int32	-
DF37P	Number of satellites in view	-	-	uint8	-
DF38P	Inter-frequency bias mask	-	-	uint16	-
DF39P	Code bias value	-	-	int16	In decimeters units, 0x7FFF = not valid or unknown
DF40P	Restart mask	-	-	uint32	-
DF41P	Bias dataset mask	-	-	uint8	Bit #0 = nominal IFB (1=present) Bit #1 = estimated IFB (1=present) Bit #2…Bit #7 = Reserved (future) (Bit #0 is the LSB)
DF42P	GLONASS ICB L1/L2 flag	-	-	uint1	1 = available 0 = no
DF43P	IFB type mask	-	-	uint8	Bit #0 = PSR Bit #1 = PSR rate Bit #2 = ADR rate Bit #3...Bit #7 = Reserved (future) (Bit #0 is the LSB)
DF44P	Klobuchar iono coefficient	-	-	int8	a0, a1…b3

DF	DF name	DF range	DF Res.	Data type	Data field notes
					MSB bit is a sign bit
DF45P	Nequick iono coefficient ai0, a1i	-	-	uint11, int11	ai0 is unsigned ai1 is signed (MSB bit is the sign bit)
DF46P	Nequick iono coefficient ai2	-	-	int14	MSB bit is a sign bit
DF47P	Nequick iono regions	-	-	uint5	-
DF48P	Data retransmission message	-	-	uint8	-
DF49P	Continue on the next message	-	-	uint1	0 = terminated 1 = continue on next message
DF50P	CDB writes flag	-	-	uint1	0 = no 1 = CDB write
DF51P	Test ID	-	-	uint8	-
DF52P	Test parameters	-	-	-	The length depends on the test ID
DF53P	Response ID	-	-	uint10	Message response identifier–a response message is requested (0x0000 means no response required)
DF54P	Message response	-	-	uint16	The content depends on the input message, which has requested it
DF55P	Auxiliary data type mask	-	-	uint8	-
DF56P	Compact metrics mask (signal quality)	-	-	-	-
DF57P	Message transmission interval	-	0.1 s	int16	0xFFFF = never, 0 = always
DF64P	CPU timestamp	0-4294967295	977.5171 ns	uint32	Cpu timestamp in steps of 977.5171 ns
DF65P	Acc. raw x	-32768 to 32767	0.061 mg	int16	Raw X-axis acceleration Full scale = ±2 g
DF66P	Acc. raw y	-32768 to 32767	0.061 mg	int16	Raw Y-axis acceleration Full scale = ±2 g
DF67P	Acc. raw z	-32768 to 32767	0.061 mg	int16	Raw Z-axis acceleration Full scale = ±2 g
DF68P	Gyro raw x	-32768 to 32767	4.37 mdps/LSB	int16	Raw X-axis angular rate In milli degree per second unit. Full scale = ±143 dps
DF69P	Gyro raw y	-32768 to 32767	4.37 mdps/LSB	int16	Raw Y-axis angular rate In milli degree per second unit. Full scale = ±143 dps
DF70P	Gyro raw z	-32768 to 32767	4.37 mdps/LSB	int16	Raw Z-axis angular rate In milli degree per second unit. Full scale = ±143 dps
DF71P	Sensor type	-	-	uint8	0x03 for odometer 0x18 for temperature 0x0E for speed data 0x12 for rear wheels speeds 0x1E for accelerometer 0x1F for gyroscope
DF72P	Time ID	0-15	-	uint4	0 = GPS

DF	DF name	DF range	DF Res.	Data type	Data field notes
					1 = GLONASS 2 = QZSS 3 = Galileo 4 = SBAS 7 = COMPASS 10 = NavIC (IRNSS) 14 = UTC 5, 6, 8, 9, 11…13 = Reserved 15 = not valid
DF73P	Latitude	-3.24*10^8 to 3.24*10^8	0.001 [arcsec] $--GGA	int32	-
DF74P	Longitude	-6.48*10^8 to 6.48*10^8	0.001 [arcsec] $--GGA	int32	-
DF75P	Height	-524287 to 524287	0.1 [m] $--GGA	int20	-524288 = 0x80000 = not valid
DF76P	Velocity horizontal	-524287 to 524287	0.01 m/s	int20	-
DF77P	Velocity vertical	-524287 to 524287	0.01 m/s	int20	-
DF78P	Course angle	0 to 3599	0.1 [deg]	int16	0 to 3599 = valid course angle. 0x8000 = not valid. Other values are not valid.
DF79P	Standard deviation of North position error	0 to 1048575	0.01 m	uint20	0xFFFFF = not valid
DF80P	Standard deviation of East position error	0 to 1048575	0.01 m	uint20	0xFFFFF = not valid
DF81P	Standard deviation of up position error	0 to 1048575	0.01 m	uint20	0xFFFFF = not valid
DF82P	Signal identifier	-	-	uint16	See Section 4.2.1: Inter-frequency bias mask (DF38P) for details
DF83P	Standard deviation of North velocity error	0 to 1048575	0.001 m/s	uint20	0xFFFFF = not valid
DF84P	Standard deviation of East velocity error	0 to 1048575	0.001 m/s	uint20	0xFFFFF = not valid
DF85P	Standard deviation of up velocity error	0 to 1048575	0.001 m/s	uint20	0xFFFFF = not valid
DF86P	Tracking mode	-	-	uint8	See Section 4.2.2: Signal identifier and tracking mode (DF82P and DF86P) for details
DF87P	Time validity	0 to 15	-	uint4	0 = NO TIME The system has no sense of time. No RTC, GNSS, or stored (flash) time is available. 1 = flash TIME The current time was read from a flash. Could be very old and is essentially the same as NO TIME. 2 = TOW TIME The time of week has been read from the navigation data, but not the week number (WN). 3 = USER TIME Time was set by the USER through a command.

DF	DF name	DF range	DF Res.	Data type	Data field notes
					4 = USER RTC TIME The RTC time was set by the USER (this is depreciated). 5 = RTC TIME The time difference from the last saved fix is higher than 1 hour. 6 = RTC TIME ACCURATE The time difference from the last saved fix is lower than or equal to 1 hour. 7 = APPROX TIME A time has been downloaded from the constellation, but the last ephemeris time is > 300 s old. 8 = ACCURATE TIME Either POSITION_TIME or EPHEMERIS_TIME (an accurate time). Accurate time is a status that is stored when the GNSS engine is restarted using a warm start command and the system had a time validity of 9 or 10. Anytime validity that is >= 8 can be considered an accurate time. 9 = POSITION TIME The time has been corrected using the position (an accurate time). 10 = EPHEMERIS TIME Time set from downloaded ephemeris tow. Time is not accurate (millisecond). 11 … 15 = Reserved
DF88P	Expected error in latitude	-524287 to 524287	0.01 m	int20	0x80000 = Not valid
DF89P	Expected error in longitude	-524287 to 524287	0.01 m	int20	0x80000 = Not valid
DF90P	Expected error in altitude	-524287 to 524287	0.01 m	int20	0x80000 = Not valid
DF91P	RMS value of the standard deviation of the range inputs to the navigation process	0 to 1048575	0.01	uint20	0xFFFFF = Not valid
DF92P	Standard deviation of semimajor axis of error ellipse	0 to 1048575	0.01 m	uint20	0xFFFFF = Not valid
DF93P	Standard deviation of semi-minor axis of error ellipse	0 to 1048575	0.01 m	uint20	0xFFFFF = Not valid
DF94P	Orientation of semimajor axis of error ellipse	-32767 to 32767	0.1 degrees from true North	int16	0x8000 = Not valid
DF95P	GNSS constellation mask	-	32	uint32	Refer to UM3428 (Appendix B: Acronyms and reference documents) [P21,L04]
DF96P	GNSS multi-frequency constellation mask	-	32	uint32	to UM3428 (Appendix B: Acronyms and reference documents) [P21,L05]
DF97P	STGRS fields value	-32767 to 32767	0.1	int16	Each field is the value of the residual in [dm] of the corresponding bit in the GNSS satellite mask
DF98P	Temperature	-256 to 256	1° Celsius	int16	Temperature in degree Celsius
DF99P	Raw temperature	0 to 255	1° Celsius	uint8	Raw temperature from a thermal sensor.
DF100P	Calibration	0 to 1	-	uint1	Thermal sensor calibration 0 = Not calibrated

DF	DF name	DF range	DF Res.	Data type	Data field notes
					1 = Calibrated
DF101P	TTFF	0 ms to 42949672.95 ms	10 µs	uint32	Time to first fix in 10 µs steps.
DF102P	FE selector	-	-	uint1	Front-end selector. 0: internal front-end. 1: external STA5635 front-end
DF103P	NB FE registers	-	-	uint8	Number of front-end registers
DF104P	FE register address	-	-	uint16	Front-end register address
DF105P	FE register value	-	-	uint16	Front-end register value
DF106P	Odometer	0 to 4294967295	-	uint32	Unsigned odometer count
DF107P	Reverse	0 to 1	-	uint1	Reverse status 0 = Forward 1 = Reverse
DF108P	Reserved	-	-	-	Refer to UM3428 (Appendix B: Acronyms and reference documents) [P21,L04]
DF109P	cmd_type	-	-	uint5	1 = PPS_IF_ON_OFF_CMD 5 = PPS_IF_PULSE_DURATION_CMD 7 = PPS_IF_PULSE_DATA_CMD 8 = PPS_IF_FIX_CONDITION_CMD 12 = PPS_IF_TIMING_DATA_CMD
DF110P	fix mode	-	-	uint2	1 = NOFIX. 2 = 2DFIX. 3 = 3DFIX.
DF111P	pulse duration	0 to 1000000000	-	uint30	Pulse duration [ns]
DF112P	Config block	1 to 3	-	uint2	Indicates one of the configuration blocks: 1 = Current configuration (RAM) 2 = Default configuration 3 = NVM stored configuration
DF113P	Satellite type	-	-	uint5	
DF114P	Debug data type mask	-	-	uint8	ST internal debug information
DF115P	Band	1 to 4	-	uint4	1 = Band 1 (GPS L1CA, QZSS L1CA, GAL E1, BDS B1I, IRNSS L5) 2 = Band 2 (GPS L2C, QZSS L1C, GAL E6, BDS B1C) 3 = Band 3 (GPS L5 cnav, QZSS L2C, GAL E5, BDS B2A) 4 = Band 4 (QZSS L5)
DF116P	STNMA type ID	1 to 12	-	uint6	1 = status on/off 2 = NS 3 = Reserved 4 = TSL 5 = MACSEQ flags 6 = PK 7 = MACV 8 = DSMV 9 = PKRV

DF	DF name	DF range	DF Res.	Data type	Data field notes
					10 = ALERT 11 = GETPK 12 = CLRPK 13 = SETMTR 14 = GETMTR 15 = CLRMTR 16 = SETITN 17 = GETITN 18 = CLRITN 19 = CLRAM 20 = CLRKROOT 21 = NMA_STATUS 22 = GETDSM 23 = SETDSM
DF117P	Status fix authenticated only	0 to 1	-	uint1	0 = OFF, no fix authenticated 1 = ON, fix only with authenticated satellites
DF118P	Velocity North	-524287 to 524287	0.01 m/s	int20	-524288 = Not valid
DF119P	Velocity East	-524287 to 524287	0.01 m/s	int20	-524288 = Not valid
DF120P	Height	-1500 m to 100000 m	0.1 m	int21	Heigh
DF121P	Code bias value	-	-	int20	In centimeter units, 0x80000 = Not valid or unknown
DF122P	Register address	0 to 255	-	uint8	Index of a FE register
DF123P	Safe State	0 to 255	-	uint8	0 = BOOT 1 = Normal 2 = FAULT 3 = FAULT-STOP
DF124P	SIS error code	0 to 255	-	uint8	255 = No error Cf SIS error code Table 10
DF125P	Hardware error code	0 to 255	-	uint8	255 = Invalid (see list of hardware fault codes in ADD)
DF126P	Metrics mask 2	-	-	uint32	1-bit x metric, M2 = Number of bits set

4.2.1 Inter-frequency bias mask (DF38P)

The meaning of the inter-frequency bias mask bits is described in the following table:

Table 8. DF38P inter-frequency bias mask

Bit	Code-bias
0	GPS L2C vs. L1 C/A
1	GLONASS f02 vs. f01 (central tone)
2	BeiDou B2I vs. B1I
3	GPS L5 vs. L1 C/A
4	Galileo E5a vs. E1 OS
5	Galileo E5b vs. E1 OS

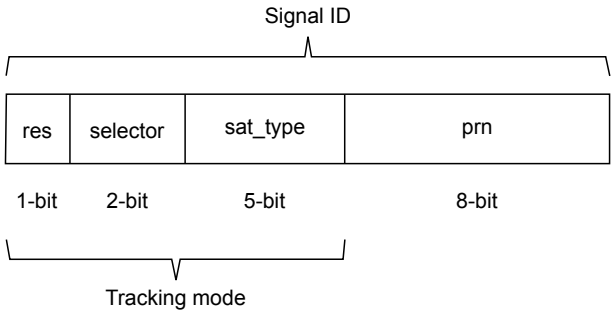
Bit	Code-bias
6	Galileo E6 vs. E1 OS
7	BeiDou B2a vs. B1I
9	BeiDou B1c vs B1I
10	BeiDou B3I vs B1I
11	BeiDou B2b vs B1I
12…15	Reserved

Note: Bit #0 is the LSB.

4.2.2 Signal identifier and tracking mode (DF82P and DF86P)

A signal identifier is an unsigned 16-bit number structured as showed in the following figure.

Figure 2. Signal identifier structure



The most significant 8 bits define the tracking mode (DF86P).

The “sat_type” represents the constellation ID as specified in UM3428 (refer to Appendix B: Acronyms and reference documents) [P21,L04].

The “prn” field is set to the corresponding RTCM3 data field according to each constellation (in case the RTCM3 data field length is lower than 8 bits then only the less significant bits will be used, and the remaining bits are set to zero).

Table 9. Signal ID constellation encoding

Constellation	RTCM3 data field for PRN
GPS	DF009
GLONASS	DF038
Galileo	DF252
QZSS	DF429
BeiDou	DF488
NavIC (IRNSS)	DF394

The “selector” identifies specific tracking modes of the signal components, for example, data vs. pilot, I vs. Q component etc. The “res” bit shall be reserved for future uses and kept to zero. The “prn” usually starts from ‘1’, a “prn” of value zero is not admitted and shall be used to identify special signal ids (for example, not valid ids). The concatenation of “selector” and “sat_type” uniquely identifies the tracking mode.

4.3 Receiver status and safety (RSS)

This message reports the receiver status and safety.

Table 10. Receiver status and safety (RSS)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	1 for receiver status and safety.
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GPS ext. week number	DF18P	50	16	Best time converted to GPS system time
Leap seconds, GPS-UTC	DF054	66	8	Converted to GPS-UTC
Safety info	-	74	1	0 = not available
Protocol version flags	-	75	7	0 to 3
Firmware version	DF19P	82	24	0xFFFFFF = N/A
Safe state	DF123P	106	8	Present only on Teseo APP2 - Reserved on Teseo VI.
SIS error code	DF124P	114	8	Present only available on Teseo APP2 - Reserved on Teseo VI.
Hardware error code	DF125P	122	8	Present only available on Teseo APP2 - Reserved on Teseo VI.
Timing/PPS status	DF01P	130	8	0 = ok 1...255 = do not use/not available
Time best validity	DF87P	138	4	-
Constellation alarm mask	DF21P	142	32	1-bit per constellation: 0 = ok 1 = excluded
Monitor alarm mask	DF22P	174	32	Monitor alarm mask. 1-bit per monitor (see Table 12): 0 = ok 1 = alarm
GNSS constellation mask	DF95P	206	32	-
GNSS multi-frequency constellation mask	DF96P	238	32	-
NCO clock drift	-	270	32	0.0001 Hz (signed int) (present only if protocol version flag is 2 or more)
Time best satellite type	DF113P	-	-	(present only if the protocol version flag is 3 or more)
Sat type not available mask	DF95P	307	32	Satellite constellation mask for which IFB monitor status cannot be computed (present only if the protocol version flag is 3 or more).

Note: The constellation alarm mask is the consolidation of all constellation masks reported by each monitor with an alarm status bit set. It may contain inactive constellations and must be considered in relation with GNSS constellation mask and GNSS Multifrequency constellation mask to consider only relevant bits.

Note: Timing/PPS status consolidates PPSOBSM, PPSM, SYSTM, PLM, CLKESTM bits from monitor alarm mask.

Table 11. SIS error code

Value	Description
0	HWM configuration
1	SIS message timeout

Value	Description
2	Monitor timeout
3	SIS memory allocation
4	Unknown message type
5	Unknown message command
6	SIS initialization
7	Reserved
8	MTU check
9…254	Reserved
255	No error

Table 12. Monitor alarm mask

ID	Name	Description (0 = ok, 1 = alarm)	Fault stop (Teseo APP2 only)
0	SIS	Global SIS alarm	Yes
1	CIM-L1	Observable integrity	-
2	HWM	Hardware failure	Yes
3	IFM	Wideband interference	-
4	RFM	RF tuners	Yes
5	SYSTM	System time integrity	-
6	NMAM	Navigation message authentication	-
7	IFBM	Inter-frequency biases	-
8	NVMM	NVM write-rate integrity	-
9	PPSOBSM	PPS vs. observable epoch	-
10	CWM	Narrow-band interference	-
11	PPSM	Timing and PPS integrity	-
12	CLKESTM	RX clock estimate integrity	-
13	ECM	E2E counter mismatch	-
14	ECRC	E2E CRC failure	-
15	EFM	E2E frame error	-
16	ASM	Antenna sensing	-
17	DCM	Data corruption	Yes
18	PLM	Protection level monitor	-
19	SPFM	Spoofing monitor	-
20	MTM	Message timing monitor	-
21	EMAC	E2E MAC verification failure	-
22…31	NA	Reserved	-

Note: The monitors with the "FAULT_STOP" column set to "Yes" in Table 10. Receiver status and safety (RSS) are considered unrecoverable. An action is expected from the external host to restart the Teseo APP2.

4.4 Receiver configuration and control (RCC)

Receiver configuration and control are implemented by exchanging the same message type.

The input version of RCC is used to set the firmware configuration, while the output version is used to report the current configuration.

The basic configuration elements are 32-bit words, organized in pages of 16 consecutive elements.

The output RCC message reports the current configuration. At startup, all configuration pages are reported in the output (one RCC message for each page), then the configuration of a specific page or all pages can be requested using the TXREQ input message (see Section 4.4: Receiver configuration and control (RCC) for details).

Table 13. Receiver configuration and control (RCC)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	2 for receiver configuration and control
Response ID	DF53P	20	10	For output it is always 0x0000
Config. block	DF112P	30	2	For output, it indicates one of the configuration blocks: 1 = current configuration (RAM) 2 = default configuration 3 = NVM stored configuration. For input not used, it can be 0.
Config. page number	DF25P	32	8	-
Continue on the next message	DF49P	40	1	0 = end 1 = continue (for output only)
CDB writes flag	DF50P	41	1	0 = no 1 = write (for input only)
Config. page mask	DF26P	42	16	1-bit per line, N = number of bits set
Config. word	DF27P	58	32*N	Up to 16 words

If the “Continue on next message” flag is set, then there is a subsequent RCC message, otherwise the current message is the last of the current reading sequence.

The input RCC message allows to update one or more lines of a specified page. One page can be updated each time.

The “config page mask” specifies which lines have to be written in the page, where the bit# 0 (that is, the least significant bit) represents the Line 0, the bit# 1 the Line 1, and so on. To write on a double type, 2 consecutive bits lines of “Config page mask” shall be set (even + odd consecutive bits) else the double write will not succeed.

In the case of the RCC input message, if the response ID field is different from 0x0000 then a response message is requested. In such case, the value of the response can be interpreted according to Table 13. Receiver configuration and control (RCC).

If the “CDB writes flag” is set, then the configuration reported by the current RCC input message will be stored in CDB, otherwise it is stored only in the “current” configuration.

“N” is the number of lines to write inside the page, and it can be calculated by counting the number of bits set in the config page mask; the number of subsequent 32-bit “Config word” fields must be exactly N. The lines reported in the config word field are sorted in ascending ordered, from the line with the lowest index to the one with the highest index.

The subsequent RCC message (if any) in input shall be issued after the RESP message with the corresponding response ID has been received.

In the case the response is not received in two fix periods (typically 2 seconds for 1 Hz fix rate), the status of the RCC message should be considered as unknown.

4.5 Extended PVT (EPVT)

This message reports the receiver PVT standard position in LLH coordinates, plus extended fix information.

Table 14. Host integrity / extended PVT

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	21 for extended PVT
Reference station ID	DF003	20	12	Invalid = 0x3FF
ITRF realization year	DF021	32	6	Reserved for future use Must be set to invalid = 0x3F
GPS quality indicator (fix status)	DF28P	38	4	$--GGA (0 = Fix not available or invalid)
Data status (RMC A/V field)	-	42	1	0 = data valid, 1 = navigation receiver warning
Fix frequency mode	-	43	1	0 = single frequency fix 1 = multi-frequency fix
Fix integrity (RAIM)	-	44	1	0 = not checked 1 = checked
RFU	-	45	1	-
Number of satellites in use	DF29P	46	8	$--GGA (Invalid = 0xFF)
Number of satellites in view	DF37P	54	8	Invalid = 0xFF
HDOP	DF30P	62	8	0-25.4 Invalid = 0xFF
VDOP	DF30P	70	8	0-25.4 Invalid = 0xFF
PDOP	DF30P	78	8	0-25.4 Invalid = 0xFF
Geoidal separation,centimeters	DF31P	86	15	$--GGA 0x4000 = not valid
Age of differentials	DF32P	101	24	$--GGA Invalid = 0xFFFFFF
Differential reference station ID	DF33P	125	12	$--GGA Invalid = 0x3FF
Time ID	DF72P	137	4	Time ID Not valid = 0xF
Time validity	DF87P	141	4	-
GNSS epoch time	DF16P	145	30	1 ms resolution Not valid = 0x3FFFFFFF
Extended week number	DF18P	175	16	Incl. roll-over The field is not valid if the GNSS epoch time is set to 0x3FFFFFFF: in such case 0xFFFF will be reported.
Leap seconds, GPS-UTC	DF054	191	8	Mark as 0xFF for not-valid / not-provided

Data field	DF	Bit position	Bits	Notes
Latitude	DF73P	199	32	0.001 [arcsec] $--GGA 0x80000000 = not valid
Longitude	DF74P	231	32	0.001 [arcsec] $--GGA 0x80000000 = not valid
Height	DF120P	263	21	0.1 [m] steps. Height from mean-sea-level (geoid)
Velocity horizontal	DF76P	284	20	0.01 [m/s] 0x80000 = not valid
Velocity vertical	DF77P	304	20	0.01 [m/s] 0x80000 = not valid
Course angle	DF78P	324	16	0.1 [deg] 0 to 3599 = valid course angle. 0x8000 = not valid. Other values not valid.
Protection level horizontal	-	340	16	0.01 [m] (N/A = 0xFFFF)
Protection level vertical	-	356	16	0.01 [m] (N/A = 0xFFFF)
Protection level angle	-	372	16	0.01 [deg] (N/A = 0xFFFF)
Receiver clock bias	-	388	32	[mm] 0x80000000 = not valid
Receiver clock drift	-	420	32	[cm/s] 0x80000000 = not valid
Velocity North	DF118P	452	20	0.01 [m/s] 0x80000 = not valid
Velocity East	DF119P	472	20	0.01 [m/s] 0x80000 = not valid
gdop	-	492	8	Geometric dilution of precision
tdop	-	500	8	Time dilution of precision
Reserved	-	508	5	-

1. In the case “GPS quality indicator (fix status)” is 0, then the following fields are not valid, regardless of their reported values:
   - Geoidal separation, meters
   - Latitude
   - Longitude
   - Height
   - Velocity horizontal
   - Velocity vertical
   - Course angle
   - Fix frequency mode
   - Fix constellation mode
   - Fix integrity
2. In the case of 2D fix, the height field is set to not valid (0x80000).

4.6 Position quality metrics (POSQM)

This message reports the position quality metrics data.

Table 15. Signal quality metrics (POSQM)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	5 positions for quality metrics
GNSS epoch time	DF16P	20	30	1 ms resolution
Time ID	DF72P	50	4	Time ID Not valid = 0 x F
Position quality metrics mask	-	54	16	1-bit for each metric, M = Number or bit set
Position quality metrics value	-	70	-	See Table 16. Position quality metrics mask

Table 16. Position quality metrics mask

Bit position	Bit	Position quality metrics type	Res.	Data size (bits)
54	0(1)	Protection level, horizontal	dm	20 (u)(2)
55	1...15	Reserved	-	-

1. *Bit #0 is the LSB.*
2. *u means unsigned.*

Note: The position quality metrics value field reports the position quality metrics enabled in the position quality metrics mask in the same order. Each field size is specified in the data size column of Table 16. Position quality metrics mask. For unsigned 20-bit fields the 0xFFFFF value means NOT VALID.

4.7 Signal quality metrics 2 (SIGQM2)

This message reports the calculated signal quality metrics (SQM) and autocorrelation metrics (ACM) values in a more compact format with respect to the SIGQM message.

There are 2 versions of the SIGQM2 message format with metrics mask bit 31 to identify the 2 versions.

Table 17. Signal quality metrics 2 (SIGQM2) with metric mask DF22P bit 31 = 0

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	26 for signal quality metrics 2
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
GNSS satellite mask	DF07P	54	40	N = number of bits set
Metrics mask	DF22P	94	32	1-bit x metric, M = number of bits set bit 31 = 0
Multiple message indicators	DF23P	126	1	-
Metrics value	DF56P	127	-	See Table 19. DF56P compact metrics mask (signal quality)

Table 18. Signal quality metrics 2 (SIGQM2) with metrics mask DF22P bit 31 = 1

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	26 for signal quality metrics 2
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
GNSS satellite mask	DF07P	54	40	N = number of bits set
Metrics mask	DF22P	94	32	1-bit x metric, M = number of bits set (except bit 31) bit 31 = 1, metrics mask 2 field added.
Metrics mask 2	DF126P	126	32	1-bit x metric, M_2 = number of bits set
Multiple message indicators	DF23P	158	1	-
Metrics value	DF56P	159	-	See Table 19 and Table 20

Table 19. DF56P compact metrics mask (signal quality)

Bit position	Bit DF22P	Metrics	Band(1)	Res.	Size (bits) in DF56P
94	0(2)	Signal strength (CN0)	1	1 dB Hz	8(u)
95	1	Carrier loop discriminator output std estimate [mdeg]	1	1	16(s)
96	2	Code loop discriminator output bias estimate [cm]	1	1	16(s)(4)
97	3	Double-delta metric, based on 5x correlations [cm]	1	1	16(s)(4)
98	4	Autocorrelation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	1	1	16(s)(4)
99	5	DSP flags (see Table 23. DSP flags)	1	-	32
100	6	Metrics flags (see Table 22. Metrics flags field encoding)	1	-	16
101	7	Satellite elevation angle	-	1 deg.	8(s)(4)
102	8	DSP flags 2 (see Table 24. DSP flags 2)	1	-	32
103	9	Reserved	-	-	-
104	10	Signal strength (CN0)	2	1 dB Hz	8(u)(3)
105	11	Carrier loop discriminator output std estimate [mdeg]	2	1	16(s)(4)
106	12	Code loop discriminator output bias estimate [cm]	2	1	16(s)(4)
107	13	Double-delta metric, based on 5x correlations [cm]	2	1	16(s)(4)
108	14	Autocorrelation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	2	1	16(s)(4)
109	15	DSP flags (see Table 23. DSP flags)	2	-	32
110	16	Metrics flags (see Table 22. Metrics flags field encoding)	2	-	16
111	17	Reserved	-	-	-
112	18	DSP flags 2 (see Table 24. DSP flags 2)	2	-	32

Bit position	Bit DF22P	Metrics	Band(1)	Res.	Size (bits) in DF56P
113	19	Reserved	-	-	-
114	20	Signal strength (CN0)	3	1 dB Hz	8(u)(3)
115	21	Carrier loop discriminator output std estimate [mdeg]	3	1	16(s)(3)
116	22	Code loop discriminator output bias estimate [cm]	3	1	16(s)(3)
117	23	Double-delta metric, based on 5x correlations [cm]	3	1	16(s)(3)
118	24	Autocorrelation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	3	1	16(s)(3)
119	25	DSP flags (see Table 23. DSP flags)	3	-	32
120	26	Metrics flags (see Table 22. Metrics flags field encoding)	3	-	16
121	27	Reserved	-	-	-
122	28	DSP flags 2 (see Table 24. DSP flags 2)	3	-	32
123	29	Reserved	-	-	-
124	30	User1	-	-	32(u)(4)
125	31	Metrics mask 2 enable / disable. 1 = enable 0 = disable	-	-	-

1. *See Table 21. Signals position.*
2. *Bit #0 is the LSB.*
3. *u means unsigned.*
4. *s means signed.*

Table 20. DF56P compact metrics mask 2 (signal quality)

Bit position	Bit DF126P	Metrics	Band(1)	Res.	Size (bits) in DF56P
126	0(2)	Signal strength (CN0)	4	1 dB Hz	8 (u)
127	1	Carrier loop discriminator output std estimate [mdeg]	4	1	16 (s)
128	2	Code loop discriminator output bias estimate [cm]	4	1	16 (s) (4)
129	3	Double-delta metric, based on 5x correlations [cm]	4	1	16 (s) (4)
130	4	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	4	1	16 (s) (4)
131	5	DSP flags (see Table 23. DSP flags)	4	-	32
132	6	Metrics flags (see Table 22. Metrics flags field encoding)	4	-	16
133	7	Reserved	-	-	-
134	8	DSP flags 2 (see Table 24. DSP flags 2)	4	-	32
135	9	Reserved	-	-	-
136	10	Signal strength (CN0)	5	1 dB Hz	8 (u) (3)
137	11	Carrier loop discriminator output std estimate [mdeg]	5	1	16 (s) (4)
138	12	Code loop discriminator output bias estimate [cm]	5	1	16 (s)(4)
139	13	Double-delta metric, based on 5x correlations [cm]	5	1	16 (s)(4)

Bit position	Bit DF126P	Metrics	Band(1)	Res.	Size (bits) in DF56P
140	14	Autocorrelation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	5	1	16 (s)(4)
141	15	DSP flags (see Table 23. DSP flags)	5	-	32
142	16	Metrics flags (see Table 22. Metrics flags field encoding)	5	-	16
143	17	Reserved	-	-	-
144	18	DSP flags 2 (see Table 24. DSP flags 2)	5	-	32
145	19	Reserved	-	-	-
146	20	Signal strength (CN0)	6	1 dB Hz	8 (u)(3)
147	21	Carrier loop discriminator output std estimate [mdeg]	6	1	16 (s)(4)
148	22	Code loop discriminator output bias estimate [cm]	6	1	16 (s)(4)
149	23	Double-delta metric, based on 5x correlations [cm]	6	1	16 (s)(4)
150	24	Auto-Correlation metric #1, based on 10x correlations (Parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	6	1	16 (s)(4)
151	25	DSP flags (see Table 23. DSP flags)	6	-	32
152	26	Metrics flags (see Table 22. Metrics flags field encoding)	6	-	16
153	27	Reserved	-	-	-
154	28	DSP flags 2 (see Table 24. DSP flags 2)	6	-	32
155	29	Reserved	-	-	-
156	30	User2	-	-	32 (u)(3)
157	31	Reserved	-	-	-

1. *See Table 21. Signals position.*
2. *Bit #0 is the LSB.*
3. *u means unsigned.*
4. *s means signed.*

Note:

- *For unsigned 8-bit fields the 0xFF value means NOT VALID.*
- *For signed 8-bit fields the 0x80 value means NOT VALID.*
- *For unsigned 16-bit fields the 0xFFFF value means NOT VALID.*
- *For signed 16-bit fields the 0x7FFF value means NOT VALID. In case of double-delta metric and autocorrelation metric, if their values exceed the signed 16-bit representation limits, it saturates to 32767 (for positive values) or -32768 (for negative values).*
- *For unsigned 32-bit fields the 0xFFFFFFFF value means NOT VALID.*
- *For signed 32-bit fields the 0x7FFFFFFF value means NOT VALID.*

Table 21. Signals position

GNSS system	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6
GPS	L1CA	L2C	L5	L1C	-	-
GLONASS	G1	G2	-	-	-	-
Galileo	E1	E5B	E5A	E6	-	-
QZSS	L1CA	L2C	L5	L1C	-	-
BeiDou	B1I	B2I	B2A	B1C	B2B	B3I
NavIC (IRNSS)	L5	-	-	-	-	-

The meaning of the bits in the metrics flags field is explained in Table 22. Metrics flags field encoding. They indicate which metrics threshold triggers OFDE exclusion.

Table 22. Metrics flags field encoding

Bit	Metrics
0[1]	Signal strength (CN0)
1	Carrier loop discriminator
2	Code loop discriminator
3	Double-delta metric
4	Autocorrelation metric
5	Code-carrier divergence
6	Doppler to range-rate divergence
7	Dual frequency carrier phase delta gradient
8	Inter-frequency code bias residual
9	Pseudorange threshold exceeded
10	Drop detection
11	False lock detection
12	Spoofing detection
13..15	Reserved

1. *Bit #0 is the LSB.*

On Teseo VI the autocorrelation metrics is supported only for GPS L1CA, Galileo E1 and BeiDou B1I.

On Teseo VI the double-delta metrics is not supported for GPS L1C & L5, Galileo E1 & E5 & E6, QZSS L1C & L5, BeiDou B1C & B2A.

Table 23. **DSP flags**

Bit#	Description
0[1]	Availability 0 = Not available 1 = Available
1	Preamble locked 0 = Not locked 1 = Locked
3:2	Multipath indicator 0 = No 3 = Strong
4	Loss of lock indicator 0 = No loss of lock 1 = Lock lost
6:5	Reserved
7	Preamble polarity 0 = Normal; 1 = Reversed
8	Half-cycle ambiguity 1 = Not fixed; 0 = Fixed
13:9	Reserved
14	Frequency 1 = Main freq. (L1); 0 = Dual freq. (L2, L5, etc.)
15	Cycle slip indicator (at current epoch vs. previous one) 0 = No cycle slip detected 1 = Cycle slip occurred
16	Reserved
17	Pseudorange measurement integrity 0 = OK 1 = Not reliable
18	Carrier phase measurement integrity 0 = OK 1 = Not reliable
19	Drop detection alarm 0 = OK 1 = Alarm
20	Code alarm 0 = OK 1 = Alarm
21	Preamble propagation 0 = Not propagated 1 = Propagated

Bit#	Description
22:24	Code alarm intensity 0..7. Valid when the code alarm is high (1), reporting the intensity [min (0), max(7)]
25	Spoofing 0 = No spoofing 1 = Possible spoofing
26	Reserved
27	Reserved
28	Reserved
29	Reserved
31:30	Reserved

1. *Bit #0 is the LSB.*

Table 24. DSP flags 2

Bit#	Description
0	Reserved

4.8 Observable quality metrics (OBSQM)

This message reports the calculated observable quality metrics (OBSQM) values.
There are 2 versions of the OBSQM message format with metrics mask bit 31 to identify the 2 versions.

Table 25. Observable quality metrics (OBSQM) with metrics mask bit 31=0

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	6 for observable quality metrics
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
GNSS satellite mask	DF07P	54	40	N = number of bits set
Metrics mask	DF22P	94	32	1-bit x metric, M = number of bits set bit 31 = 0
Multiple message indicators	DF23P	126	1	-
Metrics value	DF24P	127	32	N*M elements

Table 26. Observable quality metrics (OBSQM) with metrics mask bit 31=1

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050,)
Subtype ID	DF02P	12	8	6 for observable quality metrics
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
GNSS satellite mask	DF07P	54	40	N = number of bits set

Data field	DF	Bit position	Bits	Notes
Metrics mask	DF22P	94	32	1-bit x metric, M = number of bits set (except bit 31) bit 31 = 1, metrics mask 2 field added
Metrics mask 2	DF22P	126	32	1-bit x metric, M_2 = number of bits set
Multiple message indicators	DF23P	158	1	-
Metrics value	DF24P	159	32	N*(M+M_2) elements

Table 27. DF22P metrics mask (observable quality)

Bit position	Bit	Metrics	Band	Res.
94	0(1)	Code-carrier divergence (main freq.)	1	1
95	1	Code-carrier divergence (dual freq.)	2	1
96	2	Code-carrier divergence (triple freq.)	3	1
97	3	Doppler to range-rate divergence (main freq.)	1	1
98	4	Doppler to range-rate divergence (dual freq.)	2	1
99	5	Doppler to range-rate divergence (triple freq.)	3	1
100	6	Dual-frequency carrier phase delta gradient (main, dual)	1,2	1
101	7	Dual-frequency carrier phase delta gradient (main, triple)	1,3	1
102	8	Inter-frequency code bias residual (main, dual)	1,2	1
103	9	Inter-frequency code bias residual (main, triple)	1,3	1
104	10	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (main)	1	1
105	11	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (dual)	2	1
106	12	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (triple)	3	1
107	13	Carrier phase pseudorange diff (main freq.)	1	1
108	14	Carrier phase pseudorange diff (dual freq.)	2	1
109	15	Carrier phase pseudorange diff (triple freq.)	3	1
110	16..30	Reserved	-	-
125	31	Metrics mask 2 enable / disable. 1 = enable, 0 = disable	-	-

1. *Bit #0 is the LSB.*

Table 28. **DF22P metrics mask 2 (observable quality)**

Bit position	Bit	Metrics	Band	Res.
126	0[1]	Code-carrier divergence (F4)	4	1
127	1	Code-carrier divergence (F5)	5	1
128	2	Code-carrier divergence (F6)	6	1
129	3	Doppler to range-rate divergence (F4)	4	1
130	4	Doppler to range-rate divergence (F5)	5	1
131	5	Doppler to range-rate divergence (F6)	6	1
132	6	Dual-frequency carrier phase delta gradient (F1, F5)	1,5	1
133	7	Dual-frequency carrier phase delta gradient (F1, F6)	1,6	1
134	8	Inter-frequency code bias residual (F1, F5)	1,5	1
135	9	Inter-frequency code bias residual (F1, F6)	1,6	1
136	10	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F4)	4	1
137	11	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F5)	5	1
138	12	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F6)	6	1
139	13	Carrier phase pseudorange diff (F4)	4	1
140	14	Carrier phase pseudorange diff (F5)	5	1
141	15	Carrier phase pseudorange diff (F6)	6	1
142	16	Dual-frequency carrier phase delta gradient (F1, F4)	1,4	1
143	17	Inter-frequency code bias residual (F1, F4)	1,4	1
144	18...31	Reserved	-	-

1. *Bit #0 is the LSB.*

0x7FFFFFFF means saturation/not valid for metrics code carrier divergence, doppler to range rate divergence, dual frequency carrier phase delta gradient, inter frequency code bias residual.

Pseudorange, carrier phase and doppler STD are encoded on a single 32-bit word for each band. The bits #31 to #20 represent the pseudorange STD (0xFFF means saturation/not valid), the bits #19 to #10 represent the carrier phase STD (0x3FF means saturation/not valid), and the bits #9 to #0 represent the doppler STD (0x3FF means saturation/not valid). Refer to Table 21. Signals position for signal position from the GNSS system.

4.9 Data retransmission request (TXREQ)

This input message allows the user to force retransmission of the requested message as specified by the message retransmission ID fields. The actual retransmission will happen at the next slot available.

Table 29. **Data retransmission request (TXREQ)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	18 for data retransmission request
Response ID	DF53P	20	10	-
Retransmission message ID	DF48P	30	8	See Table 30
Additional data		38	N_i	N_i is the number of additional bits required for the specified retransmission message ID

Table 30. Retransmission message ID

ID	Requested message	N_i	Comment
0	1006 stationary RTK reference station ARP with height	0	Not available on Teseo APP2
1	1013 system parameters	0	-
2	1019 GPS ephemerides	0	-
3	1020 GLONASS ephemerides	0	-
4	1042 BDS satellite ephemeris data	0	-
5	1044 QZSS ephemerides	0	-
6	1046 Galileo I/NAV satellite ephemeris data	0	-
7	GLONASS inter-channel biases (ICB)	0	-
8	Inter-frequency biases (IFB)	0	-
9	Iono model parameters (IONOPAR)	0	-
10	Receiver configuration and control (RCC)	24	-
11	Firmware version (FWVER)	0	-
12	Aux message–read chip ID (AUX/CHIPID)	0	-
13	Reserved		-
14	Aux message–front-end dump (AUX/FEDUMP)	1 or 9	-
15	Pulse per second (PPS)	5	-
16	ST AGPS (STAGPS)	10	Not available on Teseo APP2
17	Almanac (ALMANAC)	14	Not available on Teseo APP2
18	1041 NavIC (IRNSS) ephemerides	0	-
19	GNSS OSNMA (STNMA)	6	Not available on Teseo APP2
20	TXREQ_AUX_CUSTOTP_READ	26	-
21	Reserved for future use	-	-
22	Aux message ID	8-9	-
23...255	Reserved for future use	-	-

Table 31. RCC retransmission additional data

Data field	DF	Bit position	Bits	Notes
Config. page number	DF25P	38	8	0 to 63, or 255 for all pages
Config. page mask	DF26P	46	16	1-bit per page, N=number of bits set
Config. block	DF112P	62	2	Indicates one of the configuration blocks: 1 = current configuration (RAM) 2 = default configuration 3 = NVM stored configuration

Table 32. AUX-FEDUMP retransmission additional data

Data field	DF	Bit position	Bits	Notes
FE selector	DF102P	38	1	0: internal FE, 1: external STA5635 FE

Data field	DF	Bit position	Bits	Notes
Register address	DF122P	39	8	0 to max. number of FE registers. This field is optional. If omitted, all registers are reported

Table 33. PPS retransmission additional data

Data field	DF	Bit position	Bits	Notes
cmd_type	DF109P	38	5	7 = PPS_IF_PULSE_DATA_CMD 12 = PPS_IF_TIMING_DATA_CMD

Table 34. ALMANAC retransmission additional data

Data field	DF	Bit position	Bits	Notes
GNSS ID	DF06P	38	4	-
Band	DF115P	42	4	-
PRN	Refer to Table 9. Signal ID constellation encoding	46	6	0 means all Almanacs of given GNSS ID.

Table 35. Auxiliary message (ID 22) retransmission additional data

Data field	DF	Bit position	Bits	Notes
Aux data types ID	DF55P	38	8	Refer to Table 64, all ID types except TTFF (not allowed) and FEDUMP (refer to Table 36).

Table 36. Auxiliary message (ID 22, type FEDUMP) retransmission additional data

Data field	DF	Bit position	Bits	Notes
Aux data type ID	DF55P	38	8	6: FEDUMP
FE selector	DF102P	46	1	0: internal FE, 1: external STA5635 FE

Table 37. GNSS OSNMA (STNMA) (ID 19) retransmission additional data

Data field	DF	Bit position	Bits	Notes
STNMA type ID	DF116P	38	6	1 : NMAONOFF 11: GETPK 14: GETMTR 17: GETITN 22: GETDSM

Table 38. CUSTOTP_READ retransmission additional data

Data field	DF	Bit position	Bits	Notes
Offset	-	38	16	Offset in bytes from where to start reading the data. Offset must be larger than or equal to 0. Offset + size must be lower than or equal to 9215.
Size	-	54	10	The number of bytes to read.

If the response ID field is different from 0x0000, then an output response message (RESP) will be sent with the same value for the response ID field. In such case, the value of the response can be interpreted according to Table 62. Response meaning.

The subsequent TXREQ message (if any) shall be issued after the RESP message with the corresponding response ID has been received.

In the case the response is not received in two fix periods (typically 2 s for 1 Hz fix rate), the status of the TXREQ message should be considered as unknown.

4.10 GLONASS inter channel biases (ICB)

This message reports the GLONASS inter-channel biases (output version) and it allows to update the GLONASS inter-channel biases (input version).

Table 39. GLONASS inter channel biases (ICB)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	7 GLONASS for Interchannel biases
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GLONASS ICB L1 flag	DF42P	50	1	1 = available 0 = no
GLONASS ICB L2 flag	DF42P	51	1	1 = available 0 = no
GLONASS ICB Value(s)	DF39P	52	16*14 or *28	Length based on flags

GLONASS inter-channel bias (ICB) tables are composed of 14 consecutive code-bias values, corresponding to GLONASS channels -7… +6. Each GLONASS carrier (L1 or L2) has its independent ICB table. When both L1 and L2 flags are set, then ICB values for L1 are first.

4.11 Inter-frequency biases (IFB)

This message reports both the nominal and estimated inter-frequency biases (output version) and it allows to update the nominal inter-frequency biases (input version).

Table 40. Inter-frequency biases (IFB) output message

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	8 for inter-frequency biases
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
Bias data set mask	DF41P	50	8	P = number or bits set Bit # 0 = nominal Bit # 1 = estimate Bit # 2...Bit # 7 = RFU
Inter-frequency bias mask	DF38P	58	16	N = number of bits set (see Table 42 for details)
IFB type mask	DF43P	74	8	M = number of bits set (see Table 7 for details)
IFB value(s)	DF121P	82	20* N*M*P	IFB centimeter values in the order specified in Table 42

Table 41. Inter-frequency biases (IFB) input message

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	8 for inter-frequency biases

Data field	DF	Bit position	Bits	Notes
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
Bias data set mask	DF41P	50	8	P = number of bits set Bit #0 = nominal Bit #1 = estimate Bit #2...Bit # 7 = RFU
Inter frequency bias mask	DF38P	58	16	N = number of bits set (see Table 42 for details)
IFB type mask	DF43P	74	8	M = number of bits set (see Table 7 for details)
IFB value(s)	DF39P	82	16* N*M*P	IFB decimeter values in the order specified in Table 42

Bias data set mask (DF41P) shall be used to identify specific ICB/IFB data sets. For example, Bit #0 = nominal values, Bit #1 = estimates.

IFB values (DF39P and DF121P), when present, shall follow in increasing bit-order of DF43P, as specified in the following table.

Table 42. IFB values order and format

Mask Bit # / Order in the DF39P field	Description
0(1)	IFB [cm] between GPS L1 and L2 carriers
1	IFB [cm] between GLONASS L1 and L2 carriers
2	IFB [cm] between BeiDou B1I and B2I carriers
3	IFB [cm] between GPS L1 and L5 carriers
4	IFB [cm] between Galileo E5a and E1 carriers
5	IFB [cm] between Galileo E5b and E1 carriers
6	IFB [cm] between Galileo E6 and E1 carriers
7	IFB [cm] between BeiDou B2a and B1I carriers
8	IFB [cm] between GPS L1C and L1CA carriers
9	IFB [cm] between BeiDou B1C and B1I carriers
10	IFB [cm] between BeiDou B3I and B1I carriers
11	IFB [cm] between BeiDou B2B and B1I carriers

1. *Bit #0 is the LSB.*

4.12 Ionospheric model parameters (IONOPAR)

This message reports the ionospheric model parameters (output version) and it allows to update the ionospheric model parameters (input version).

Table 43. Ionospheric model parameters (IONOPAR)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Sub type ID	DF02P	12	8	9 for ionospheric model parameters
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	

Depending on the GNSS ID (DF06P), the following parameters follow:

Table 44. Klobuchar (GPS, BeiDou, NavIC (IRNSS), CNAV)

Data Field	DF	Bit position	Bits	Notes
Klobuchar iono coefficient	DF44P	54	8*N	N = 8

Table 45. Nequick (Galileo)

Data field	DF	Bit position	Bits	Notes
Nequick iono coefficient ai0	DF45P	54	11	
Nequick iono coefficient ai1	DF45P	65	11	
Nequick iono coefficient ai2	DF46P	76	14	
Nequick iono regions	DF47P	90	5	

4.13 Receiver suspend (SUSPEND)

This input message is used to put the device in the suspended state.

Table 46. Receiver suspend (SUSPEND)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	15 for receiver suspend

An AUX-SYSSTAT system status message is sent when the device is suspended.

4.14 Receiver restart (RESTART)

This input message is used to restart a device in the suspended state. It can also be used to reset the device. If the device is not suspended when restart message is received, then a suspend is performed before the restart.

Table 47. Receiver restart (RESTART)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	16 for receiver restart
Restart mask	DF40P	20	32	

Table 48. **DF40P restart mask definition**

Bit	Mask
0[1]	Delete all almanacs from NVM
1	Delete all ephemeris from NVM
2	Delete last user position from NVM
3	Invalidate the real-time clock (RTC)
4	Reserved
5	Delete UTC parameters from NVM
6	Delete ionosphere model parameters from NVM
7	Delete code bias compensation parameters from NVM
8…30	Reserved
31	Software reset

1. *Bit# 0 is the LSB.*

In case of software reset, an AUX-SYSSTAT system status message is sent when the device is restarted.

4.15 Navigation data frame (NDF)

For navigation data frame (NDF) definition, BKG proposal (https://software.rtcm-ntrip.org/wiki/NDF) has been adopted in this document.

Note: The above URL belongs to a third party. It is active at document publication, however STMicroelectronics shall not be liable for any change, move or inactivation of the URL or the referenced material.

RTCM3 standard messages (such as 1019, 1020, etc.) provide decoded ephemeris data, but there are no messages to provide the raw data frames downloaded from the GNSS satellites, which contain more information (such as almanacs data, integrity data, and so on). For that reason, RTCM3 proprietary messages have been implemented, and they provide a transport format for raw navigation data frames (NDF).

This message is in line with the recently introduced MSM observation messages. MSM messages are generic and message type numbers are reserved for up to 16 GNSS systems. Similarly, NDF data messages are also claimed as generic, that is, their high-level structure is the very same for each GNSS and signal.

The following table describes the generic NDF message structure. Then for each available GNSS we specify signals containing binary data and provide recommendations for data framing.

A GNSS application can use NDF data as it is, or it can first convert it into (for example, already standardized MT 1019, 1020 and so on) ephemeris structures for further processing archiving.

Table 49. **Message header 4075 format**

Data field	DF	Type	Bit position	Bits	Notes
Message number	DF002	uint12	0	12	4075 (proprietary number for this purpose)
Reference station ID	DF003	uint12	12	12	Stream identification
Reserved field	-	uint2	24	2	Reserved bits, may be used to separate different type 4075 message, always 0 for NDF
Frame count (FC)	-	uint6	26	6	Number of frame entries to follow
Frame entry	-	-	32	It depends on FC and frame size	Frame data according to the Table 50
TOTAL	-	-	-	32 + frames	-

Table 50. Message header 4050-42 format

Data field	DF	Type	Bit position	Bits	Notes
Message number	DF002	uint12	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	uint8	12	8	42 for NDF
Reference station ID	DF003	uint12	20	12	Stream identification
Frame count (FC)	-	uint6	32	6	Number of frame entries to follow
Frame entry	-	-	38	Depends on FC and frame size	Frame data according to the following table
TOTAL	-	-	-	38 + frames	-

The message allows grouping multiple frames into one block. These can be:

- Multiple signals for one satellite,
- Multiple satellites at one time or,
- Multiple frames for one signal,
- Multiple satellite systems.

In addition, combinations of these are possible. For real-time raw frame transport, the combination of these is most useful.

Table 51. Frame entry 4075 format

Data field	DF	Type	Bit position	Bits	Notes
Satellite system	-	uint4	32	4	0 = GPS 1 = GLONASS 2 = Galileo 3 = SBAS 4 = QZSS 5 = BDS 6 = NavIC (IRNSS)
Satellite number	-	uint6	36	6	Satellite ID, index from MSM satellite mask bit field (0...63, see DF394)
Extended sat info	-	uint4	42	4	Specific for each GNSS system, frequency number+7 for GLONASS
Signal type	-	uint5	46	5	Signal type specification, index from MSM signal mask bit field (0...31, see DF395)
Epoch time	-	uint30	51	30	Epoch time, specific for the satellite system is always 30 bits (see Table 52)
Continuous tracking	-	bit(1)	81	1	Tracking this satellite frame data was continuous (1 = continuous, 0 not continuous, or unset)
Frame data size (N)	-	uint12	82	12	A number of bits to follow
Frame data	-	-	94	N	Bit data from satellite (see data section below)
TOTAL	-	-	-	62 + N	-

Table 52. Frame entry 4050-42 format

Data field	DF	Type	Bit position	Bits	Notes
Satellite system	-	uint4	38	4	0 = GPS 1 = GLONASS 2 = Galileo 3 = SBAS 4 = QZSS 5 = BDS 6 = NavIC (IRNSS)
Satellite number	-	uint6	42	6	Satellite ID, index from MSM satellite mask bit field (0..63, see DF394)
Extended sat info	-	uint4	48	4	Specific for each GNSS system, frequency number+7 for GLONASS
Signal type	-	uint5	52	5	Signal type specification, index from MSM signal mask bit field (0..31, see DF395)
Epoch time	-	uint30	57	30	Epoch time, specific for the satellite system is always 30 bits (see Table 53)
Continuous tracking	-	bit(1)	87	1	Tracking this satellite frame data was continuous (1 = continuous, 0 not continuous, or unset)
Frame data size (N)	-	uint12	88	12	A number of bits to follow
Frame data	-	-	100	N	Bit data from satellite (see data section below)
TOTAL	-	-	-	62 + N	-

The layout of a frame block always follows this structure, so unknown satellite systems or satellites can be skipped in messages with more than one frame.

Table 53. Epoch time (accuracy in milliseconds, equal to MSM)

Satellite system	DF number(s)	Notes
GPS	DF004	In milliseconds (0..604799.999 s)
GLONASS	DF416 (3 bit) + DF034 (27 bit)	Like for MSM, day of week 0 = Sunday, 6 = Saturday, 7 = unknown) + time of day in ms (0 to 86400.999 s)
Galileo	DF248	Equals GPS
SBAS	-	Equals GPS
QZSS	DF428	Equals GPS
BDS	DF427	Similar to GPS, but with a 14 leap second difference
NavIC (IRNSS)	DF72P	Equals GPS

Frame data (implementation recommendation)

While the format generally has variable bit length support, to reduce confusion about the data contents the standard should define the bit sizes and data to be transferred for all existing satellite systems. Data should always include checksums and other non-informational parts of the transmission.

- GPS
  - Old style: 300 bits including the checksums
    - Inversed bits must be corrected, so the data can be directly read without taking care of this.
    - Carry bits from previous blocks must be corrected, so the parity of the first block does not consider any other non-zero bits.
    - Parity inside the 10 blocks needs to consider previous carry bits.
  - CNAV-Style: 300 bits including the CRC

- SBAS
  - 250 bits including CRC
- QZSS
  - 300 bits for GPS-compatible signals
    - See GPS for specification
  - 250 bits for SBAS-compatible signal
    - See SBS for specification
  - 2000 bits for LEX signal
- Galileo
  - I/NAV 2*114 bits
- BeiDou:
  - 300 bits
- GLONASS:
  - 85 bits
- NavIC (IRNSS)
  - 286 bits

The actual encoding of the frame data reported in the message payload is specified in the following table.

Table 54. Actual encoding of data frame

Constellation	Type	Length (bits)	Length (bytes)	Notes
GPS	Subframe	300	40 (10 words)	For each 32-bit word 30 bits are used (the 2 MSB are ignored)
GLONASS	1 or 2 strings	85 or 170 (85+85)	11 or 22 (11+11 bytes)	One string for each message for strings from 1 to 5. Two strings for each message for strings from 6 to 15. For the first byte of each string the 3 MSB is ignored and the 4th is always zero. The payload is 84 bits long
Galileo	payload	228	29 (8 words)	Each message contains the payload from the I/NAV message
BeiDou	Subframe	300	40 (10 words)	For each 32-bit word 30 bits are used (the 2 MSB are ignored)
NavIC (IRNSS)	Subframe	286 (no tail)	36 (9 words)	Each message contains a subframe 1, 2, 3 or 4

Note: For GLONASS, for strings for #1 to #5 just the first 11 bytes are used, while for strings from #6 to #15 all 22 bytes are used by storing two consecutive strings (for example, strings #7 and #6). In this latter case, the first string (for example, string #n) is stored in the second part of the array (that is, from byte# 12 to #22), and the second string (for example, string# n+1) is stored in the first part of the array (that is, from byte# 1 to #11). For Galileo full I/NAV, the message reports both the even and odd pages of the I/NAV message (E1-b) without tails, encoded as specified in the Galileo ICD document, on the first 228 bits (tails removed), according to the following table:

Table 55. Galileo I/NAV full (even+odd)

#	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	EO	P	Data k 0-29 (112 bit)																													
1	Data k 30-61 (112 bit)																															
2	Data k 62-93 (112 bit)																															
3	Data k 94-111 (112 bit)																		EO	P	Data j 0-11 (16 bit)											
4	Data j 4-LSB												Reserved1																			
5	Reserved1													SAR 0-19 (22-bit)																		
6	SAR		Spare										CRCi 24-bit																	Reserved2		
7	Reserved2																															

For BeiDou, the navigation frame contains the message payload, encoded according to the following table:

Table 56. BeiDou common frame (D1/D2)

#	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		Preamble 11-bit												Rev 4-bit				FraID			SOW 8-MSB									P 4-bit		
1		SOW 12-LSB																							P 8-bit							
2																									P 8-bit							
3																									P 8-bit							
4																									P 8-bit							
5																									P 8-bit							
6																									P 8-bit							
7																									P 8-bit							
8																									P 8-bit							
9																									P 8-bit							

For NavIC (IRNSS) subframe, the message reports subframe 1, 2, 3 or 4 message without tail (6 bits), encoded as specified in the NavIC (IRNSS) SIGNAL-IN-SPACE ICD FOR SPS document, on the first 286 bits (tail removed), according to Table 49 and Table 58:

Table 57. NavIC (IRNSS) subframe 1 and 2

#	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	TLM (8 bits)								TOWC (17 bits)																	ALERT	AUTO NAV	SF ID (2 bits)		SPARE		DATA 0-1 (232 bits)	
1	DATA 2-33 (232 bits)																															
2	DATA 34-65 (232 bits)																															
3	DATA 66-97 (232 bits)																															
4	DATA 98-129 (232 bits)																															
5	DATA 130-161 (232 bits)																															
6	DATA 162-193 (232 bits)																															

#	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
7	DATA 194-225 (232 bits)																															
8	DATA 226-231 (232 bits)								CRC (24 bits)																							

Table 58. NavIC (IRNSS) subframe 3 and 4

#	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	TLM (8 bits)								TOWC (17 bits)																	ALERT	AUTO NAV	SF ID (2 bits)		SPARE	MESSAGE ID 0-1 (6 bits)	
1	MESSAGE ID 2-5 (6 bits)								DATA 0-27 (220 bits)																							
2	DATA 28-59 (220 bits)																															
3	DATA 60-91 (220 bits)																															
4	DATA 92-123 (220 bits)																															
5	DATA 124-155 (220 bits)																															
6	DATA 156-187 (220 bits)																															
7	DATA 188-219 (220 bits)																															
8	PRN ID (6 bits)								CRC (24 bits)																							

Data senders need to decide whether data with bad checksum is transferred or not. While generally data with a bad checksum may be discarded, in disturbed environments even such data may be useful, in particular when parts of the message are common to multiple satellites, or when a portion of the data is already known.

NDF as ephemeris transport

RTCM3 already has a set of navigational data messages like 1019 (GPS), 1020 (GLONASS) or planned messages like 1044 (QZSS) 1045, 1046 (Galileo). With the additional satellite systems more navigation messages become necessary and also the existing system navigation messages are changing, and thus additional formats are required.

The above message structure allows to use this message also as a replacement or enhancement of existing ephemeris messages simply by filling the message not with the real-time stream, but with all frames necessary for an ephemeris set (for example, for GPS C/A this would be subframes 1 to 3). Advantages of this approach:

- Receivers must support the frame format, so data decoding is no longer special for RTCM messages, but they can use already existing algorithms
- No assumptions are taken about which data is required and which not, or what the future use of certain reserved/spare bits might be
- Changing data formats are handled easily
- Unique structure for all satellite systems and signal types (even private services, and so on)

New signals, adhering to an existing GNSS standard, but containing different data (for example, new augmentation signals or pseudowires) can directly employ this standard.

4.16 Test message (TEST)

The test message allows to send a test command (identified by the test ID DF51P data field) to the receiver. Additional test data (if it is needed) can be provided in the test parameters DF52P data field, and its length depends on the test ID.

Table 59. Test message (TEST)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	20 for test message
Test ID	DF51P	20	8	-
Test parameters	DF52P	28	N * 8	N depends on test ID

Table 60. DF51P test ID definition

Test ID	Test name	Number	Type
0	DSP verification	28	7 signed 32-bit words
1	RF TEST ON	8	2 unsigned 32-bit words (“sat id” and “CN0 threshold”)
2	RF TEST ADD	8	2 unsigned 32-bit words (“sat id” and “CN0 threshold”)
3	RF TEST OFF	0	-
4	Antenna sensing set operating mode	1	1 unsigned byte with operating mode to set. 0 = AUTO 1 = MANUAL
5	Antenna sensing set configuration	3	3 unsigned bytes: Power on/off: 0 = do nothing 1 = ON 2 = OFF RF path to set: Must be 1 = EXTERNAL Stop processing: 0 = START 1 = STOP
6	Restore firmware configuration parameters to default values	0	-
7	Front-end write register (FEWRITE)	8	2 unsigned 16 bits: • FE selector • FE register address. 1 unsigned 32 bits: • FE register value.
8...15	TBD(1)	TBD	-
16	Standby (standby)	0	-
17	Serial number write (SN_WRITE)	1 to 241	10 bits: resp_id. 2 bits: reserved. 8 to 1928 bits: serial number string (maximum 240 characters) with a terminating null byte.
18...19	TBD	TBD	-
20	Force system in standby (FORCESTANDBY)	6	10 bits: resp_id. 32 bits: RTC counter time out (seconds) to generate internal wake-up (0 = disabled). 1 bit: Logic of the STANDBY_IN pin • 0: a high to low level transition wakes up the system.

Test ID	Test name	Number	Type
			• 1: a low to high level transition wakes up the system. 1 bit: Deactivation of pull-up and pull-down • 0: pull-up and pull-down are automatically set according to wake logic configured in the previous bit. • 1: pull-up and pull-down both deactivated. 1 bit: sensor interrupt • 0: deactivation of the sensor interrupt. • 1: activation of the sensor interrupt to act as wake-up in case of move.
21	HW standby pin configuration (HWSTANDBY)	2	10 bits: resp_id 1 bit: HW standby activation • 0 : disable HW standby. • 1 : enable HW standby. 1 bit : pull-down • 0 : disable pull-down on standby pin. • 1 : enable pull-down on standby pin. 1 bit : pull-up • 0 : disable pull-up on standby pin. • 1 : enable pull-up on standby pin. *Note: That enabling pull-up and pull-down at the same time is not possible and returns a RESP error.*
22	Customer OTP write (CUSTOTP_WRITE)	22 to 38	10 bits: resp_id 2 bits: reserved 16 bits: Offset in bytes from where the data should be written. Offset must be aligned to start of ECC chunk (16 bytes). Offset must be larger than or equal to 4096. Offset + size must be lower than or equal to 9215. 10 bits: The number of bytes to write: 16 or 32 bytes. 6 bits: reserved (4 or 8) x 32 bits: OTP data.
23...255	TBD	TBD	-

1. *TBD stands for "to be defined".*

Note: Enabling pull-up and pull-down at the same time is not possible and returns a RESP error.

Example of usage of RF test mode

The following command sequence (given as an example) allows the tracker to continuously search for satellites 16 and 10 in RF_TEST_MODE. The last 32-bit parameter is the minimum CN0 threshold [dB] at which satellite can be tracked.

Note: The commands are described using the TESEO-SUITE test plan tool grammar.

```
# Enable RF test, satellite 16 added to the RF_TEST searching list
SENDRTCM "[DF002]999,[DF02P]20,[DF51P]1,[32]16,[32]25"
# Add satellite 10 to the RF_TEST searching list
SENDRTCM "[DF002]999,[DF02P]20,[DF51P]2,[32]10,[32]25"
```

The satellites added in the RF_TEST list must be available in the signal with signal strength higher than 25 dB in our example to get an effective RF test.

Here are the same commands expressed in bytes (as sent by a host):

```
D3-00-0C-3E-71-40-10-00-00-01-00-00-00-01-90-56-DA-BC
D3-00-0C-3E-71-40-20-00-00-00-A0-00-00-01-90-52-8A-6D
```

4.17 Response message (RESP)

The response message provides the response for the input message which has requested it. The response ID is used to identify the input message which has requested the response.

The encoding of the response data field depends on the type of the message which has requested it.

Table 61. Response message (RESP)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	19 for response message
Response ID	DF53P	20	10	-
Response	DF54P	30	16	Response to the message associated to the response ID

Table 62. Response meaning

Response	Notes
0x0000	OK
0x0001	Error
0x0002 … 0xFFFF	RFU

Note: It is not guaranteed that the response is provided. In case it is provided, the response will be issued in max two fix periods (typically 2 s for 1 Hz fix rate).

4.18 Auxiliary message (AUX)

The AUX message provides an output auxiliary message to report auxiliary data in the RTCM3 output stream.

Table 63. Auxiliary message (AUX)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	22 for auxiliary message
Aux data type ID	DF55P	20	8	-
Auxiliary data		28	32*N	N depends on the Aux data type ID

The auxiliary data are encoded on bytes (N). The number of words N depends on the auxiliary data type, as specified in the following center:

Table 64. Auxiliary IDs

Aux ID	Auxiliary message name	N	Notes
0	CPU results (CPU usage in 0.0001% unit)	20	-
1	Chip ID data	68	-
2	Temperature (TEMP)	4	-
3	System status (SYSSTAT)	4	-
4	TTFF	4	-
5	Reserved		-
6	FEDUMP	2...129	-
7	EXCMEMDUMP	2...19	-
8	Reserved	-	-
9	Serial number (SN)	1 to 241	Not available on Teseo APP2
10	Reserved for future use	TBD	-
11	Customer OTP read	35	-
12...255	Reserved for future use	TBD	-

Chip ID (CHIPID)

Table 65. Auxiliary data CPU results (CPU)

Data Field	DF	Bit position	Bits	Notes
Reserved	-	28	32	-
Reserved	-	60	32	-
Reserved	-	92	32	-
Reserved	-	124	32	-
CPU usage	-	156	32	CPU usage in 0.0001 % unit

Note: Bit0 is the LSB.

Table 66. **Auxiliary data chip ID (CHIPID)**

Data field	DF	Bit position	Bits	Notes
Chip ID	-	28	128	-
BCS version	-	156	32	-
Reserved	-	188	32	-
DCF version	-	220	32	DCF version
DCF 388	-	252	64	DCF value offset 0x388
DCF 389	-	316	64	DCF value offset 0x389
DCF 38a	-	380	64	DCF value offset 0x38a
DCF 38b	-	444	64	DCF value offset 0x38b
DCF 38c	-	508	64	DCF value offset 0x38c

Note: Bit #0 is the LSB.

Temperature (TEMP)

Table 67. **Auxiliary data temperature (TEMP)**

Data field	DF	Bit position	Bits	Notes
Temperature	DF98P	28	16	Temperature in degree Celsius
Reserved	-	44	8	Reserved
Calibration	DF100P	52	1	Thermal sensor calibration (0 = not calibrated, 1 = calibrated)

System status (SYSSTAT)

Table 68. **Auxiliary data system status (SYSSTAT)**

Bit position	Bits	System status	Notes
28..57	31..2	Reserved	-
58	1	OSCI32 OK status	0: Not OK 1: OSCI32 output OK
59	0	GNSSLIB	0: suspended, 1: running

Auxiliary data system status (SYSSTAT)

This message is sent once after the first fix.

Table 69. **Auxiliary data time to first fix (TTFF)**

Data field	DF	Bit position	Bits	Notes
TTFF	DF101P	28	32	Time to first fix in step of 10 µs.

Note: Bit #0 is the LSB.

Front-end dump (FEDUMP)

This message dump registers of a selected front-end.

Table 70. **Auxiliary data front-end dump (FEDUMP)**

Data field	DF	Bit position	Bits	Notes
FE selector	DF102P	28	1	0: internal FE, 1: external STA56635 FE
NB FE registers	DF103P	29	8	Number of FE registers following (address + value)
FE register address	DF104P	37	16	Address of FE register
FE register value	DF105P	53	16	Value of FE register
…	-	-	-	-

Note: Bit #0 is the LSB.

Serial number (SN)

This message provides serial number.

Table 71. **Auxiliary data serial number (SN)**

Data field	DF	Bit position	Bits	Notes
Serial number	-	28	8 to 1928	Serial number string (240 characters maximum) with terminating null byte. A character is on 8 bits.

Note: Bit #0 is the LSB.

Customer OTP read

This message provides customer OTP data on one or several lines of 8 x 32 bits for OTP data. This is dependent on the requested size to be read.

Table 72. **Auxiliary data customer OTP data**

Data field	DF	Bit position	Bits	Notes
Reserved	NA	28	4	-
Offset	-	32	16	Offset where OTP data has been read.
OTP data 0	-	48	32	OTP data or 0 (depending on the requested size).
OTP data 1	-	80	32	OTP data or 0 (depending on the requested size).
OTP data 2	-	112	32	OTP data or 0 (depending on the requested size).
OTP data 3	-	144	32	OTP data or 0 (depending on the requested size).
OTP data 4	-	176	32	OTP data or 0 (depending on the requested size).
OTP data 5	-	208	32	OTP data or 0 (depending on the requested size).
OTP data 6	-	240	32	OTP data or 0 (depending on the requested size).
OTP data 7	-	272	32	OTP data or 0 (depending on the requested size).

Note: Bit #0 is the LSB.

4.19 Set message transmission interval (SETMTI)

The SETMTI message sets the message transmission interval (MTI) for a specified message in the RTCM3 output stream.

Table 73. **Set message transmission Interval (SETMTI)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	23 for set message transmission interval
Target message number	DF002	20	12	-
Target subtype ID	DF02P	32	8	-
MTI	DF57P	40	16	Signed integer (-1 = never, 0 = always)

The target message number is the ID of the RTCM3 message to configure.

In case of proprietary messages, the target subtype ID specifies which messages' MTI shall be configured. In case of standard messages, the subtype ID is ignored.

It allows to set any MTI value (from 0=always to 3276.7 s with resolution of 0.1 sec). Moreover, -1 means message disabled and 0 means every time the message is available. Its value is represented on a 16-bit signed integer, which means that -1 can be represented in two's complement (0xFFFF).

For the message IDs 1002, 1010, 1077, 1087, 1097, 1117, 1127, only the MTI value of 0 or -1 are allowed. Moreover, message IDs 1002, 1010 are not compatible with message IDs 1077, 1087, 1097, 1117, 1127 (MSM7), so both groups must not be enabled at the same time.

Messages (except IDs 1002, 1010, 1077, 1087, 1097, 1117, 1127) can be down-sampled changing the MTI value.

The following messages do not support oversampling. MTI value should not be lower than the reported GNSS fix ratio:

RCC, IONOPAR, ICB, IFB, STDTM, EPVT, IFBDATA, STGST, STGRS, STGSA, STGBS, STGSV, and POSQM.

In the case of SETMTI message, the MTI value is stored in RAM, so it will be reset to the stored configuration value at the next reset or power off.

Receiver configuration and control (RCC) message, described in Section 4.4: Receiver configuration and control (RCC), can be used to change CDB MTI configuration instead.

4.20 RF status (RFS)

This message reports the current RF front end status (notch filter status, RF automatic gain control status, jamming detection status, noise floor, and antenna sensing status).

Table 74. **RF status (RFS)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	24 for RF status
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
Reported status mask	-	50	8	Bit #0: CW Bit #1: AGC Bit #2: WBJ/IFM Bit #3: noise floor Bit #4: antenna sensing Bit #5: antispoofing Bit #6: RFU Bit #7: extended data

Data field	DF	Bit position	Bits	Notes
Reported status data	-	58	-	Reported status data are present in the same order as the previous mask bits are set (order bit 0-7) and only present if the corresponding bits are set to 1. See Table 75, Table 76, Table 77,Table 78. Noise floor data (reported status mask bit 3 = 1), Table 79, Table 80, Table 81 and Table 83

Each group of status data is present in the message only if the corresponding bits in the reported status mask are set.

Table 75. CW data (reported status mask bit 0 = 1)

Data field	DF	Bits	Notes
IFDATA CW detection mask	-	4	IF1…IF4 1 = CW detected, 0 = unknown Bit #0: IF1 CW detected Bit #1: IF2 CW detected Bit #2: IF3 CW detected Bit #3: IF4 CW detected
CW notch insertion status mask	-	8	CNF1…CNF8 1 = ON (inserted) 0 = OFF Bit #0: CNF1 inserted Bit #1: CNF2 inserted Bit #2: CNF3 inserted Bit #3: CNF4 inserted Bit #4: CNF5 inserted Bit #5: CNF6 inserted Bit #6: CNF7 inserted Bit #7: CNF8 inserted
CW affected constellation mask	DF21P	32	-
CW candidate validity mask	-	8	1 = candidate valid 0 = unknown or not reported Bit #0: CW candidate 0 Bit #1: CW candidate 1 Bit #2: CW candidate 2 Bit #3: CW candidate 3 Bit #4: CW candidate 4 Bit #5: CW candidate 5 Bit #6: CW candidate 6 Bit #7: CW candidate 7
CW candidate #0 power/ freq.	-	32	Only a number of candidates (0…8) equal to the number of bits set to “1” into the “CW candidate validity mask” is reported

Data field	DF	Bits	Notes
CW candidate #1 power/ freq.	-	32	Only a number of candidates (0…8) equal to the number of bits set to “1” into the “CW candidate validity mask” is reported
CW candidate #2 power/ freq.	-	32	
CW candidate #3 power/ freq.	-	32	
CW candidate #4 power/ freq.	-	32	
CW candidate #5 power/ freq.	-	32	
CW candidate #6 power/ freq.	-	32	
CW candidate #7 power/ freq.	-	32	

CW candidate power/freq. is a 32-bit word structured in the following way:

- bits from #0 to #18 encode the cosine value (expressed in two's complement). The real frequency value in the intermediate frequency domain can be calculated with this formula:

$$freq\_real = \frac{32 \times 1023000}{\pi} \times \text{acos}\left(\frac{freq\_cos}{262144}\right) \quad (10)$$

  bits from #19 to #31 encode the power values divided by 4 of the interferers detected.
- Bit #0 is the LSB

Table 76. AGC data (reported status mask bit 1 = 1)

Data field	DF	Bits	Notes
AGC validity mask	-	4	Reserved
Reserved	-	12	Reserved
Reserved	-	12	
AGC external G2	-	12	
AGC external GC	-	12	

Table 77. WBJ/IFM data (reported status mask bit 2 = 1)

Data field	DF	Bits	Notes
Wide-band (IFM) jamming detection	-	6	DDC0…DDC5 1 = jamming detected, 0 = unknown Bit #0: DDC0 jamming detected Bit #1: DDC21 jamming detected Bit #2: DDC2 jamming detected Bit #3: DDC3 jamming detected

Data field	DF	Bits	Notes
			Bit #4: DDC54 jamming detected Bit #5: DDC5 jamming detected
Reserved	-	32	-

Table 78. Noise floor data (reported status mask bit 3 = 1)

Data field	DF	Bits	Notes
Noise floor DDC0	-	32	0 = unknown
Noise floor DDC1	-	32	0 = unknown
Noise floor DDC2	-	32	0 = unknown
Noise floor DDC3	-	32	0 = unknown
Noise floor DDC4	-	32	0 = unknown
Noise floor DDC5	-	32	0 = unknown

Table 79. Antenna sensing data (reported status mask bit 4 = 1)

Data field	DF	Bits	Notes
Antenna sensing power switch	-	1	0 = OFF 1 = ON
Antenna sensing op mode	-	1	0 = AUTO 1 = MANUAL
Antenna sensing RF path	-	3	0 = UNINIT 1 = EXTERNAL 2 = INTERNAL 3..7 = RFU
Antenna sensing status	-	3	0 = UNINIT 1 = NORMAL 2 = OPEN 3 = SHORT 4 = THERMAL SHUTDOWN 5 = REVERSE CURRENT 6 = OVERCURRENT 7 = ERROR

Table 80. Anti-spoofing data (reported status mask bit 5 = 1)

Data field	DF	Bits	Notes
Anti-spoofing list length/ Anti-spoofing data format	-	6	63: updated anti-spoofing data format (see Table 81) 0 to 62: N = number of satellite signal IDs in the anti-spoofing list (unsigned int); see Table 83

If the reported status mask bit 5 is 1 and the “Anti-spoofing list length/Anti-spoofing data format“ field is equal to 63, then the following fields of the message are encoded as shown in Table 81. Updated anti-spoofing data (reported status mask bit 5 = 1), otherwise if the reported status mask bit 5 is 1 and the value of “Anti-spoofing list length/Anti-spoofing data format“ field is less than 63 (that is, 0 to 62) the following fields are encoded as showed in Table 83. Legacy anti-spoofing data (reported status mask bit 5 = 1).

Table 81. Updated anti-spoofing data (reported status mask bit 5 = 1)

Data field	DF	Bits	Notes
Anti-spoofing data format version	-	4	0: Anti-spoofing data format version 0
Anti-spoofing constellation alarm mask	-	32	Reports the constellations under spoofing if the number of spoofed satellites of the same constellation is equal to or above FW configuration page 37 line 9 field 1 number. Bit #0: GPS Bit #1: GLONASS Bit #2: QZSS Bit #3: Galileo Bit #4: Compass Bit #5: NavIC (IRNSS)
Anti-spoofing list length	-	6	M = number of satellite signal IDs in the anti-spoofing list. (unsigned int)
Anti-spoofing list fields	-	16 x M	16-bit signal ID for each satellite in the anti-spoofing list. Bit #0-7: tracking mode (DF86P) Bit #8-15: prn (GLONASS prn is a satellite id 1 to 28)

Table 82. Updated anti-spoofing data version 1 (reported status mask bit 5 = 1)

Data field	DF	Bits	Notes
Anti-spoofing data format version	-	4	1: Anti-spoofing data format version 1
Anti-spoofing constellation alarm mask	-	32	Reports the constellations under spoofing if the number of spoofed satellites of the same constellation is equal to or above FW configuration page 37 line 9 field 1 number. Bit #0: GPS Bit #1: GLONASS Bit #2: QZSS Bit #3: Galileo Bit #4: Compass Bit #5: NavIC (IRNSS)
Anti-spoofing list length	-	6	M = number of satellite signal IDs in the anti-spoofing list. (unsigned int)
Anti-spoofing list fields	-	16 x M	16-bit signal ID for each satellite in the anti-spoofing list. Bit #0-7: tracking mode (DF86P) Bit #8-15: prn (GLONASS prn is a satellite id 1 to 28)
Dual antenna Anti-spoofing constellation alarm mask	-	32	Reports the constellations under spoofing on dual antenna. See notes of Anti-spoofing constellation alarm mask parameter

Data field	DF	Bits	Notes
RFU	-	32	-
RFU	-	32	-
RFU	-	32	-

Table 83. Legacy anti-spoofing data (reported status mask bit 5 = 1)

Data field	DF	Bits	Notes
Anti-spoofing list fields	-	16 x N	16-bit signal ID for each satellite in the anti-spoofing list Bit #0-7: tracking mode (DF86P) Bit #8-15: prn (GLONASS prn is a satellite id 1 to 28)

Table 84. Extended data (reported status mask bit 7 = 1)

Data field	DF	Bits	Notes
Extended status mask	-	8	Bit #0: CW Bit #1: AGC Bit #2: WBJ/IFM Bit #3: Noise floor Bit #4: antenna sensing Bit#5...7: RFU
Extended status data	-	-	Extended status data are present in the same order as the previous mask bits are set (order Bit #0..7) and only present if the corresponding bits are set to 1. See Table 85. Extended CW data (extended status mask bit 0 = 1), Table 86. Extended AGC data (extended status mask bit 1 = 1), Table 87. Extended WBJ/IFM data (extended status mask bit 2 = 1) and Table 88. Extended noise floor data (extended status mask bit 3 = 1).

Table 85. Extended CW data (extended status mask bit 0 = 1)

Data field	DF	Bits	Notes
IFDATA CW detection mask	-	4	IF5…IF8 1 = CW detected, 0 = unknown Bit #0: IF5 CW detected Bit #1: IF6 CW detected Bit #2: IF7 CW detected Bit #3: IF8 CW detected
CW notch insertion status mask	-	16	CNF9…CNF24 1 = ON (inserted) 0 = OFF Bit #0: CNF9 inserted Bit #1: CNF10 inserted Bit #2: CNF11 inserted Bit #3: CNF12 inserted Bit #4: CNF13 inserted Bit #5: CNF14 inserted Bit #6: CNF15 inserted Bit #7: CNF16 inserted

Data field	DF	Bits	Notes
			Bit #8: CNF17 inserted Bit #9: CNF18 inserted Bit #10: CNF19 inserted Bit #11: CNF20 inserted Bit #12: CNF21 inserted Bit #13: CNF22 inserted Bit #14: CNF23 inserted Bit #15: CNF24 inserted
CW candidate validity mask	-	16	1 = candidate valid 0 = unknown or not reported Bit #0: CW candidate 8 Bit #1: CW candidate 9 Bit #2: CW candidate 10 Bit #3: CW candidate 11 Bit #4: CW candidate 12 Bit #5: CW candidate 13 Bit #6: CW candidate 14 Bit #7: CW candidate 15 Bit #8: CW candidate 16 Bit #9: CW candidate 17 Bit #10: CW candidate 18 Bit #11: CW candidate 19 Bit #12: CW candidate 20 Bit #13: CW candidate 21 Bit #14: CW candidate 22 Bit #15: CW candidate 23
CW candidate #8 power/ freq.	-	32	Only a number of candidates (8…24) equal to the number of bits set to “1” into the “CW candidate validity mask” is reported
CW candidate #9 power/req.	-	32	
CW candidate #10 power/ freq.	-	32	
CW candidate #11 power/ freq.	-	32	
CW candidate #12 power/ freq.	-	32	
CW candidate #13 power/ freq.	-	32	
CW candidate #14 power/ freq.	-	32	
CW candidate #15 power/ freq.	-	32	

Data field	DF	Bits	Notes
CW candidate #16 power/ freq.	-	32	Only a number of candidates (8…24) equal to the number of bits set to “1” into the “CW candidate validity mask” is reported
CW candidate #17 power/ freq.	-	32	
CW candidate #18 power/ freq.	-	32	
CW candidate #19 power/ freq.	-	32	
CW candidate #20 power/ freq.	-	32	
CW candidate #21 Power/ Freq.	-	32	
CW candidate #22 power/ freq.	-	32	
CW candidate #23 power/ freq.	-	32	
CW fs sign mask	-	24	CW candidate 0 to 8 freq_sin sign mask: • 1= Candidate freq_sin positive sign • 0 = Candidate freq_sin negative sign CW candidate 9 to 23 freq_sin sign mask: • 1= Candidate freq_sin negative sign • 0= Candidate freq_sin positive sign Bit #0: CW freq_sin sign candidate 0 Bit #1: CW freq_sin sign candidate 1 Bit #2: CW freq_sin sign candidate 2 Bit #3: CW freq_sin sign candidate 3 Bit #4: CW freq_sin sign candidate 4 Bit #5: CW freq_sin sign candidate 5 Bit #6: CW freq_sin sign candidate 6 Bit #7: CW freq_sin sign candidate 7 Bit #8: CW freq_sin sign candidate 8 Bit #9: CW freq_sin sign candidate 9 Bit #10: CW freq_sin sign candidate 10 Bit #11: CW freq_sin sign candidate 11 Bit #12: CW freq_sin sign candidate 12 Bit #13: CW freq_sin sign candidate 13 Bit #14: CW freq_sin sign candidate 14 Bit #15: CW freq_sin sign candidate 15 Bit #16: CW freq_sin sign candidate 16 Bit #17: CW freq_sin sign candidate 17 Bit #18: CW freq_sin sign candidate 18 Bit #19: CW freq_sin sign candidate 19

Data field	DF	Bits	Notes
			Bit #20: CW freq_sin sign candidate 20 Bit #21: CW freq_sin sign candidate 21 Bit #22: CW freq_sin sign candidate 22 Bit #23: CW freq_sin sign candidate 23

CW candidate power/freq. is a 32-bit word structured in the following way:

- bits from #0 to #18 encode the cosine value (expressed in two's complement). The real frequency value in the intermediate frequency domain can be calculated with this formula:
- bits from #19 to #31 encode the power values divided by 4 of the interferers detected.

$$freq\_real = \frac{32 \times 1023000}{\pi} \times \text{acos}\left(\frac{freq\_cos}{262144}\right) \quad (11)$$

Note: Bit #0 is the LSB.

Table 86. Extended AGC data (extended status mask bit 1 = 1)

Data field	DF	Bits	Notes
AGC validity mask	-	8	Reserved
AGC_CH1_VGA	-	6	-
AGC_CH1_PRE_VGA	-	2	-
AGC_CH2_VGA	-	6	-
AGC_CH2_PRE_VGA	-	2	-
AGC_CH3_VGA	-	6	-
AGC_CH3_PRE_VGA	-	2	-
AGC_RFA_GAIN	-	2	-

Table 87. Extended WBJ/IFM data (extended status mask bit 2 = 1)

Data field	DF	Bits	Notes
Wide-band (IFM) jamming detection	-	2	DDC6…DDC7 1 = jamming detected, 0 = unknown Bit #0: DDC6 jamming detected Bit #1: DDC7 jamming detected
Reserved	-	32	-
Reserved	-	32	-

Table 88. Extended noise floor data (extended status mask bit 3 = 1)

Data field	DF	Bits	Notes
Noise floor DDC6	-	32	0 = unknown

Data field	DF	Bits	Notes
Noise floor DDC7	-	32	0 = unknown

Table 89. Extended antenna sensing data (extended status mask bit 4 = 1)

Data field	DF	Bits	Notes
RFU	-	8	
Antenna sensing status 2	-	3	0 = UNINIT 1 = NORMAL 2 = OPEN 3 = SHORT 4 = THERMAL SHUTDOWN 5 = REVERSE CURRENT 6 = OVERCURRENT 7 = ERROR

4.21 RF AGC (RFAGC)

This message reports the current RF front-end AGC status.

Table 90. RF status (RFS)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	43 for RFAGC status
RFA gain	-	20	2	-
CH1 VGA	-	22	6	Channel 1 VGA gain
CH1 PRE VGA	-	28	2	Channel 1 PRE VGA
CH2 VGA	-	30	6	Channel 2 VGA gain
CH2 PRE VGA	-	36	2	Channel 2 PRE VGA
CH3 VGA	-	38	6	Channel 3 VGA gain
CH3 PRE VGA	-	44	2	Channel 3 PRE VGA
DBFS REF CH1	-	46	6	Wanted DBFS channel 1 (dB)
DBFS ACTL REF CH1	-	52	6	DBFS ACTL ref channel 1 (dB)
DBFS REF CH2	-	58	6	Wanted DBFS channel 2 (dB)
DBFS ACTL REF CH2	-	64	6	DBFS ACTL ref channel 2 (dB)
DBFS REF CH3	-	70	6	Wanted DBFS channel 3 (dB)
DBFS ACTL REF CH3	-	76	6	DBFS ACTL ref channel 3 (dB)
RFACTRL FSM STATE	-	82	8	RFACTRL fsm state
PREVGACTRL FSM STATE	-	90	8	PREVGACTRL fsm state
ADC OVL IQ	-	98	8	ADC OVL IQ channel 1, 2, 3
ADC OVL ON IQ	-	106	8	ADC OVL ON IQ channel 1, 2, 3
OVL CNT CH1	-	114	32	OVL CNT channel 1
OVL CNT CH2	-	146	32	OVL CNT channel 2
OVL CNT CH3	-	178	32	OVL CNT channel 3

Data field	DF	Bit position	Bits	Notes
GPS epoch time (TOW)	DF004	210	30	Best time converted to GPS system time

Note: Bit #0 is the LSB.

4.22 Firmware version (FWVER)

The FWVER message reports the current firmware version.

Table 91. Firmware version message (FWVER)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	25 for firmware version
FW ver data length	-	20	8	N, number of bytes
FW ver data string	-	28	8*N	N depends on the FW ver data length. It contains the GNSSLIB version and the binary FW version separated by semicolon ';' character. Format: GNSSLIB_<Ver>_<Rel_status>_<Type>;BINIMG_STA8xxx_<Ver>_<Rel_status>_<Type> <ver> = x.x.x.x, x.x.x, or x_x_x <Rel_status> = EAR (early), BETA, RTM (ready to market). <type> = ARM or GNU

Example of firmware ver data string: GNSSLIB_10.0.0.0_EAR_ARM; BINIMG_STA8600_6_1_2_EAR_ARM.

4.23 GNSS RAIM parameters (STGBS)

This message reports the current receiver autonomous integrity monitoring (RAIM) error parameters.

Table 92. GNSS RAIM parameters (STGBS)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	31 for GNSS RAIM parameters
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
Expected error in latitude	DF88P	50	20	0.01 meters 0x80000 = not valid
Expected error in longitude	DF89P	70	20	0.01 meters 0x80000 = not valid
Expected error in altitude	DF90P	90	20	0.01 meters 0x80000 = not valid
ID number of most likely failed satellite.	DF82P	110	16	This satellite is excluded by the RAIM or FDE algorithm. 0xFFFF = not valid
Probability of missed detection for most likely failed satellite	DF83P	126	20	Resolution = 10^{-6} 0xFFFFF = not valid

Data field	DF	Bit position	Bits	Notes
Estimated range residual of most likely failed satellite	-	146	20	Signed, 0.1 m 0x80000 = not valid
Standard deviation of bias estimate	-	166	20	Unsigned 0.01 m 0xFFFFF = not valid

4.24 GNSS pseudorange error statistics (STGST)

This message reports the current GNSS pseudorange error statistics parameters.

Table 93. GNSS pseudorange error statistics (STGST)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	30 for GNSS pseudorange error statistics
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
RMS value of the standard deviation of the range inputs to the navigation process	DF91P	50	20	Resolution = 0.01 0xFFFFF = not valid
Standard deviation of semi-major axis of error ellipse	DF92P	70	20	0.01 m 0xFFFFF = not valid
Standard deviation of semi-minor axis of error ellipse	DF93P	90	20	0.01 m 0xFFFFF = not valid
Orientation of semi-major axis of error ellipse	DF94P	110	16	0.1 degrees from true North 0x8000 = not valid
Standard deviation of North position error	DF79P	126	20	0.01 m 0xFFFFF = not valid
Standard deviation of East position error	DF80P	146	20	0.01 m 0xFFFFF = not valid
Standard deviation of up position error	DF81P	166	20	0.01 m 0xFFFFF = not valid
Standard deviation of North velocity error	DF83P	186	20	0.001 m/s 0xFFFFF = not valid
Standard deviation of East velocity error	DF84P	206	20	0.001 m/s 0xFFFFF = not valid
Standard deviation of up velocity error	DF85P	226	20	0.001 m/s 0xFFFFF = not valid

4.25 GNSS satellites in view (STGSV)

This message reports the number of satellites (SV) in view, satellite ID numbers, elevation, azimuth, and SNR value.

Table 94. GNSS satellites in view (STGSV)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	28 for GNSS satellites in view
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-

Data field	DF	Bit position	Bits	Notes
GNSS satellite mask	DF07P	54	40	N = number of bits set
Fields mask	-	94	8	Bit #0-6: 1-bit x metrics, M = number or bits set Bit #7: field mask extension is 0
Multiple message indicators	DF23P	102	1	-
Fields value	-	103	-	See Table 96

Note: Bit #0 is the LSB.

Table 95. GNSS satellites in View (STGSV) with fields mask extension

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	28 for GNSS satellites in view
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
GNSS satellite mask	DF07P	54	40	N = number of bits set
Fields mask	-	94	8	Bit #0..6: 1-bit x metrics, M = number of bits set Bit #7: field mask extension is 1
Multiple message indicators	DF23P	102	1	-
Fields mask extension	-	103	8	s
Fields value	-	111	-	See Table 96 and Table 97

Note: Bit #0 is the LSB.

Table 96. Fields mask (STGSV)

Bit position	Bit	Metrics	Band	Res.	Size (bits)
94	0	Elevation	-	1 deg	8 (s)(1)
95	1	Azimuth	-	1 deg	9 (u)
96	2	Signal strength (CN0) – 1st band (see Table 17)	1	1 dB Hz	8 (u)(2)
97	3	Signal strength (CN0)–2nd band (see Table 17)	2	1 dB Hz	8 (u)(2)
98	4	Signal strength (CN0)–3rd band (see Table 17)	3	1 dB Hz	8 (u) (2)
99	5	Signal strength (CN0)–4th band (see Table 17)	4	1 dB Hz	8 (u)(2)
100	6	Signal strength (CN0)–5th band (see Table 17)	5	1 dB Hz	8 (u)(2)
101	7	Fields mask extension	-	-	-

1. *s means signed.*
2. *u means unsigned.*

Table 97. Fields mask extension (STGSV)

Bit position	Bit	Metrics	Band	Res.	Size (bits)
103	0(1)	Signal strength (CN0)–6th band (see Table 17)	6	1 dB Hz	8 (u)(2)

Bit position	Bit	Metrics	Band	Res.	Size (bits)
104... 110	1...7	Reserved	-	-	-

1. *Bit #0 is the LSB.*
2. *u means unsigned.*

The number of fields reported in the STGSV payload corresponds to the number of bits set in the satellite mask (that is, the number of satellites reported in the message), while the number of subfields in each field corresponds to the number of bits set in the field mask.

- For unsigned 8-bit fields the 0xFF value means NOT VALID.
- For signed 8-bit fields the 0x80 value means NOT VALID.
- For unsigned 9-bit fields the 0x1FF value means NOT VALID.

4.26 GNSS DOP and active satellites (STGSA)

This message reports the GNSS receiver operating mode, satellites used in the navigation solution, and DOP values.

Table 98. GNSS DOP and Active Satellites (STGSA)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	29 for GNSS DOP and active satellites
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Mode	-	54	1	0 = manual, forced to operate in 2D or 3D mode 1 = automatic, allowed to automatically switch 2D/3D
Fix mode	-	55	2	1 = fix not available 2 = 2D, 3 = 3D
Band mask	-	57	4	Bit#0 = band 1 available Bit#1 = band 2 available Bit#2 = band 3 available Bit#3 = band mask extension is 0 M is the number of bits set in the mask on bit#0..2
HDOP	DF30P	61	8	0-25.4 Invalid = 0xFF
VDOP	DF30P	69	8	0-25.4 Invalid = 0xFF
PDOP	DF30P	77	8	0-25.4 Invalid = 0xFF
Multiple message indicators	DF23P	85	1	-
Field values	-	86	40 * M	See Table 100

Note: Bit#0 is the LSB.

Table 99. GNSS DOP and active satellites (STGSA) with extension

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	29 for GNSS DOP and active satellites
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Mode	-	54	1	0 = manual, forced to operate in 2D or 3D mode 1 = automatic, allowed to automatically switch 2D/3D
Fix mode	-	55	2	1 = fix not available, 2 = 2D, 3 = 3D
Band mask	-	57	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = band mask extension is 1 M is the number of bits set in the band mask on bit #0..2 and the band mask extension on bit 0.
HDOP	DF30P	61	8	0-25.4 Invalid = 0xFF
VDOP	DF30P	69	8	0-25.4 Invalid = 0xFF
PDOP	DF30P	77	8	0-25.4 Invalid = 0xFF
Multiple message indicators	DF23P	85	1	-
Band mask extension	-	86	8	Bi t#0 = band 4 available Bit #1 = band 5 available Bit #2 = band 6 available Bit #3 to 7 = RFU M is the number of bits set in the band mask on bit#0..2 and the band mask extension on bit#0.
Field values	-	94	40 * M	See Table 101

Note: Bit#0 is the LSB.

Table 100. STGSA field value

Data field	DF	Bit position	Bits	Notes
GNSS satellite mask	DF07P	86+40 * i (i in 0 to M-1)	40	Each bit is set so that the corresponding satellites are used in the solution for the given band

Note: Satellite ID #1 is the MSB.

Table 101. STGSA field value with band mask extension

Data field	DF	Bit position	Bits	Notes
GNSS satellite mask	DF07P	94+40 * i (i in 0 to M-1)	40	Each bit is set so that the corresponding satellites are used in the solution for the given band

Note: Satellite ID #1 is the MSB.

See Table 17. Signal quality metrics 2 (SIGQM2) with metric mask DF22P bit 31 = 0 for signal position from the GNSS system.

4.27 GNSS range residuals (STGRS)

This message reports the receiver autonomous integrity monitoring (RAIM) range residuals.

Table 102. GNSS range residuals (STGRS) fields mask extension (STGSV)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	32 for GNSS Range residuals
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Mode	-	54	1	0 = residuals were used to calculate the position given in the matching EPVT message 1 = residuals were recomputed after the EPVT position was computed
Band mask	-	55	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = band mask extension is 0 M is the number of bits set in the mask on bit #0..2
GNSS satellite mask	DF07P	59	40	Each bit is equal to 1 if the corresponding satellite is used in the solution N is the number of bits set in the mask
Multiple message indicators	DF23P	99	1	-
Fields value	DF97P	100	16 * M * N	Each field is the value of the residual in [dm] of the corresponding bit in the GNSS satellite mask for the given band. 0x8000 = not valid

Note: Bit# 0 is the LSB.

Table 103. GNSS range residuals (STGRS) with extension fields mask extension (STGSV)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	32 for GNSS range residuals

Data field	DF	Bit position	Bits	Notes
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Mode	-	54	1	0 = residuals were used to calculate the position given in the matching EPVT message 1 = residuals were recomputed after the EPVT position was computed
Band mask	-	55	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = band mask extension is 1 M is the number of bits set in the band mask on bit# 0..2 and the band mask extension on bit# 0.
GNSS satellite mask	DF07P	59	40	Each bit is equal to 1 if the corresponding satellite is used in the solution N is the number of bits set in the mask
Multiple message indicators	DF23P	99	1	-
Band mask extension	-	100	8	Bit #0 = band 4 available Bit #1 = band 5 available Bit #2 = band 6 available Bit #3 to 7 = RFU M is the number of bits set in the band mask on bit #0..2 and the band mask extension on bit #0.
Fields value	DF97P	108	16 * M * N	Each field is the value of the residual in [dm] of the corresponding bit in the GNSS satellite mask for the given band. 0x8000 = not valid

Note: Bit# 0 is the LSB.

Refer to Table 17. Signal quality metrics 2 (SIGQM2) with metric mask DF22P bit 31 = 0 for signal position from the GNSS system.

If two bands are available, the residual is reported in the following order:

- 1st sat band #1 residual,
- 1st sat band #2 residual,
- 2nd sat band #1 residual,
- 2nd sat band #2 residual,
- …

If three bands are available, the residual is in the following order:

- 1st sat band #1 residual,
- 1st sat band #2 residual,
- 1st sat band #3 residual,
- 2nd sat band #1 residual,
- 2nd sat band #2 residual,
- 2nd sat band #3 residual,
- …

For example first the residuals for the first satellite from the first band to the last band available, then the residuals for the second satellite from the first band to the last band available, and so on.

4.28 Datum reference (STDTM)

This message reports the local geodetic datum and datum offsets from a reference datum.

Table 104. Datum reference (STDTM)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	17 for datum reference
Local datum code	-	20	16	Local datum code value (see Appendix A: Local geodetic datum tables for details) 255 = default datum 0xFFFF = not available
Latitude offset	-	36	20	0.001 [arcsec] 0x80000 = not valid
Longitude offset	-	56	20	0.001 [arcsec] 0x80000 = not valid
Height offset	-	76	16	0.1 [m] $--GGA 0x8000 = not valid or not available (2D fix)
Reference datum code	-	92	8	0 = WGS84 1 = WGS72 2 = SGS85 3 = PE90 4..6 = RFU 7 = not available

Note: Bit #0 is the LSB.

4.29 Inter-frequency biases data (IFBDATA)

This message reports the nominal and estimated inter-frequency biases.

Table 105. Inter-frequency biases data (IFBDATA)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	27 for inter-frequency biases data
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
IFB est. state	-	50	8	-
Constellation alarm mask	DF21P	58	32	-
IFB mask	DF38P	90	16	N = number of bits set
IFB records		106	N * 276	-

Table 106. **IFB record structure**

Data field	DF	Bit position	Bits	Notes
IFB index	-	i*276 +106	4	Index of the related bits in the IFB mask
Tracking mode (main freq.)	DF86P	i*276 +110	8	-
Tracking mode (dual freq.)	DF86P	i*276 +118	8	-
IFB value	-	i*276 +126	16	dm
TRAIM solution	-	i*276 +142	8	0 = OK 1 = alarm 2 = unknown
Size of table	-	i*276 +150	8	-
Number of residuals	-	i*276 +158	8	-
IFB count	-	i*276 +166	8	-
PSR rate count	-	i*276 +174	8	-
ADR rate count	-	i*276 +182	8	-
IFB mean	-	i*276 +190	32	0.001 dm
PSR rate	-	i*276 +222	32	0.00001 dm/s
ADR rate	-	i*276 +254	32	0.00001 dm/s
IFB mean threshold	-	i*276 +286	32	0.001 dm
PSR rate threshold	-	i*276 +318	32	0.00001 dm/s
ADR rate threshold	-	i*276 +350	32	0.00001 dm/s

4.30 Pulse per second (PPS)

Pulse per second management is implemented by exchanging the same message type.

The input version of PPS is used to set data into PPS manager, while the output version is used to report the current PPS manager configuration.

The output PPS message reports the current configuration. The configuration can be requested using the TXREQ input message (refer to Section 4.9: Data retransmission request (TXREQ) for details).

Table 107. **Pulse per second (PPS)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	10 for pulse per second
Response ID	DF53P	20	10	For output is always 0x0000
cmd_type	DF109P	30	5	1 = PPS_IF_ON_OFF_CMD 5 = PPS_IF_PULSE_DURATION_CMD 7 = PPS_IF_PULSE_DATA_CMD 8 = PPS_IF_FIX_CONDITION_CMD 12 = PPS_IF_TIMING_DATA_CMD
Parameters	-	35	x	Refer to Table 108 and to Table 112

Note: Bit #0 is the LSB.

Table 108. PPS_IF_ON_OFF_CMD (input)

Data field	DF	Bit position	Bits	Notes
on_off	-	35	1	0 = PPS disabled. 1 = PPS enabled.

Table 109. PPS_IF_PULSE_DURATION_CMD (input)

Data field	DF	Bit position	Bits	Notes
pulse_duration	-	35	30	Pulse duration [ns]

Table 110. PPS_IF_PULSE_DATA_CMD (output)

Data field	DF	Bit position	Bits	Notes
out_mode	-	35	uint2	0 = PPS always generated. 1 = PPS generated on even seconds. 2 = PPS generated on odd seconds.
reference_time	-	37	uint4	0 = UTC 1 = GPS_UTC. 2 = GLONASS_UTC. 3 = UTC_SU 4 = GPS_UTC_FROM_GLONASS 5 =BEIDOU_UTC 6 = UTC_NTSC 7 = GST 8 = UTC_GST 9 = GPS_FROM_GST(1) GPS_UTC_FROM_GLONASS is the GPS time derived from GLONASS time applying the GPS delta time downloaded from GLONASS satellites. If the software is configured to work in GLONASS only mode, UTC(SU) is identical to UTC and GPS_UTC_FROM_GLONASS is identical to GPS_UTC.
pulse_delay	-	41	uint32	Pulse delay [ns]
pulse_duration	-	73	uint30	Pulse duration [ns]
pulse_polarity	-	103	uint1	0 = not inverted. 1 = inverted.

1. *UTC(SU) is the Soviet Union UTC, it is derived from GLONASS time applying the UTC delta time downloaded from GLONASS satellites.*

Table 111. PPS_IF_FIX_CONDITION_CMD (input)

Data field	DF	Bit position	Bits	Notes
fix_condition	DF110P	35	2	1 = NOFIX. 2 = 2DFIX. 3 = 3DFIX.

Table 112. **PPS_IF_TIMING_DATA_CMD (output)**

Data field	DF	Bit position	Bits	Notes
fix_condition	DF110P	35	2	1 = NOFIX. 2 = 2DFIX. 3 = 3DFIX.
sat_th	-	37	uint8	Minimum number of satellites for the PPS generation.
elevation_mask	-	45	uint8	Minimum satellite elevation for satellite usage in timing filtering.
constellation_mask	-	53	uint32	Satellite constellation selection for usage in timing filtering. Bit #0 = GPS Bit #1 = GLONASS Bit #3 = BeiDou Bit #7 = Galileo
gps_rf_delay	-	85	int 16	GPS path RF delay [ns]
glonass_rf_delay	-	101	int 16	GLONASS path RF delay [ns]
galileo_rf_delay	-	117	Int 16	Galileo path RF delay [ns]
beidou_rf_delay	-	133	int 16	BeiDou path RF delay [ns]

The subsequent PPS message (if any) in input shall be issued after the RESP message with the corresponding response ID is received.

In the case the response is not received in two fix periods (typically 2 seconds for 1 Hz fix rate), the status of the PPS message should be considered as unknown.

4.31 Sensor message (SENS)

Output message reports sensor message data, which is specific to the message id for each specific sensor configuration for RTCM 3 output (accelerometer, gyroscope, IMU temperature, speed data and odometer-reverse). Input commands have the same format as output messages. If input commands are correctly decoded by Teseo then these sensor data are used for navigation and Teseo returns them in output.

Table 113. **SENS message header**

Data field	DF number	Data type	Bit position	Bits	Description
Message number	DF002	uint	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	uint	12	8	64 for sensors
Number of frame entries	-	uint	20	8	Number of frame entry fields to follow.
Frame entry	-	-	28	Variable	Frame data according to subtype ID

Table 114. **Message frame for sensor common (sensor type = 0)**

Data field	DF number	Data type	Bit position	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (0 for sensor common parameters)	-
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns	-

Data field	DF number	Data type	Bit position	Bits	Description
Sensor type length	-	uint	6	Following length in steps of 4 bits (without this and previous fields). Length = 8 (32 bits)	-
Sensor common version	-	uint	2	Sensor common version. 0 x 0 = version 0, 0 x 1–0 x 3 = RFU	-
GPS epoch time (TOW)	DF004	uint	30	Best time converted to GPS system time corresponding to cpu timestamp.	-

Table 115. Message frame for odometer-reverse (sensor type = 3)

Data field	DF number	Data type	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (3 for odometer-reverse)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
Odometer	DF106P	uint	32	Unsigned odometer
Reverse	DF107P	uint	1	Reverse status 0 = forward, 1 = reverse

Table 116. Message frame for speed data (sensor type = 14)

Data field	DF number	Data type	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (14 for speed data)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
Speed	-	int	32	Speed in tenths of a kilometer per hour Ex : 505 means 50.5 km/h

Table 117. Message frame for rear wheels speeds (sensor type = 18)

Data field	DF number	Data type	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (18 for rear wheels speeds)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
left_wheel_speed	-	uint	32	Left wheel speed in kilometer per hour
right_wheel_speed	-	uint	32	Right wheel speed in kilometer per hour

Table 118. Message frame for IMU temperatue (sensor type = 24)

Data field	DF number	Data type	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (24 for IMU temperature)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
Temperature	-	uint	16	Gyro sensor temperature. Fix point value format 8.8. Floating point value can be obtained dividing by 256.
Validity	-	uint	1	Temperature validity. 0 = not valid 1 = valid.

Table 119. Message frame for accelerometer (sensor type = 30)

Data field	DF number	Data type	bits	Description
Sensor type	DF71P	uint	8	Sensor type (30 for accelerometer)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
Acc raw x	DF65P	int	16	Raw X-axis acceleration
Acc raw y	DF66P	int	16	Raw Y-axis acceleration
Acc raw z	DF67P	int	16	Raw Z-axis acceleration

Table 120. Message frame for gyroscope (sensor type = 31)

Data field	DF number	Data type	Bits	Description
Sensor type	DF71P	uint	8	Sensor type (31 for gyroscope)
cpu timestamp	DF64P	uint	32	Steps of 977.5171 ns
Gyro raw x	DF68P	int	16	Raw X-axis angular rate
Gyro raw y	DF69P	int	16	Raw Y-axis angular rate
Gyro raw z	DF70P	int	16	Raw Z-axis angular rate

Note: Fill bits (zeros) must be used to complete the last byte at the end of the message data before the CRC 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 mean 56 bytes total.

4.32 GNSS prediction ephemeris (STGPE)

This message reports the prediction ephemeris.

Table 121. GNSS prediction ephemeris (STGPE)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	11 for GNSS prediction ephemeris
GPS Epoch Time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Band mask	-	54	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = band mask extension is 0 M is the number of bits set in the mask on bit #0..2
GNSS satellite mask	DF07P	58	40	Each bit is equal to 1 if the corresponding satellite is used in the solution. N is the number of bits set in the mask
Multiple message indicators	DF23P	98	1	-
Prediction available/number of satellites	-	99 + 16 * i (i in 0 to M * N - 1)	uint2	Prediction available and number of satellites 0 = prediction ephemeris not available. 1 = prediction ephemeris available, 1 satellite used. 2 = prediction ephemeris available, 2 satellites used. 3 = reserved

Data field	DF	Bit position	Bits	Notes
Prediction age	-	99 + 16 * i (i in 0 to M * N - 1) + 1	uint8	Age of predicted ephemeris (in hours)
Prediction distance	-	99 + 16 * i (i in 0 to M * N - 1) + 11	uint6	Time distance of ephemeris (in hours) calculated from 2 satellites. Only valid if the number of satellites is 2

Note: Bit #0 is the LSB.

Table 122. GNSS prediction ephemeris (STGPE) with extension

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	11 for GNSS prediction ephemeris
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Band mask	-	54	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = band mask extension is 1 M is the number of bits set in the band mask on bit #0..2 and the band mask extension on bit #0.
GNSS satellite mask	DF07P	58	40	Each bit is equal to 1 if the corresponding satellite is used in the solution. N is the number of bits set in the mask
Multiple message indicators	DF23P	98	1	-
Band mask extension	-	99	8	Bit #0 = band 4 available Bit #1 = band 5 available Bit #2 = band 6 available Bit #3..7 = RFU M is the number of bits set in the band mask on bit #0..2 and the band mask extension on bit #0.
Prediction available/number of satellites	-	107 + 16 * i (i in 0 to M * N - 1)	uint2	Prediction available and number of satellites 0 = prediction ephemeris not available. 1 = prediction ephemeris available, 1 satellite used. 2 = prediction ephemeris available, 2 satellites used. 3 = reserved
Prediction age	-	107 + 16 * i (i in 0 to M * N - 1) + 1	uint8	Age of predicted ephemeris (in hours)
Prediction distance	-	107 + 16 * i (i in 0 to M * N - 1) + 11	uint6	Time distance of ephemeris (in hours) calculated from 2 satellites. Only valid if the number of satellites is 2

Note: Bit# 0 is the LSB.

See Table 17. Signal quality metrics 2 (SIGQM2) with metric mask DF22P bit 31 = 0 for signal position from the GNSS system.

If two bands are available, the prediction ephemeris is reported in the following order:

- 1st sat band #1 prediction ephemeris,
- 1st sat band #2 prediction ephemeris,
- 2nd sat band #1 prediction ephemeris,
- 2nd sat band #2 prediction ephemeris,
- …

If three bands are available, the prediction ephemeris is reported in the following order:

- 1st sat band #1 prediction ephemeris,
- 1st sat band #2 prediction ephemeris,
- 1st sat band #3 prediction ephemeris,
- 2nd sat band #1 prediction ephemeris,
- 2nd sat band #2 prediction ephemeris,
- 2nd sat band #3 prediction ephemeris,
- …

For example, first the prediction ephemeris for the first satellite from the first band to the last band available, then the residuals for the second satellite from the first band to the last band available, and so on.

4.33 Init time (INITTIME)

This message initializes GPS time using UTC format. The date issued with parameters day, month and year must be later than a threshold that can be changed using the configuration options (refer to UM3428 in Appendix B: Acronyms and reference documents).

Table 123. Init time (INITTIME)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	12 for Init time
Response ID	DF53P	20	10	-
Day	-	30	uint5	Day of month (01 to 31)
Month	-	35	uint4	Month (01 to 12)
Year	-	39	uint12	Year (2021 …)
Hour	-	51	uint5	Hour (00 to 23)
Minute	-	56	uint6	Minute (00 to 59)
Second	-	62	uint6	Second (00 to 59)

Note: Bit# 0 is the LSB.

If the response ID field is different from 0x0000, then a response message is requested. In such case, the value of the response can be interpreted according to Table 1. GNSS metrics.

4.34 Almanac (ALMANAC)

This input message allows the user to load the almanacs data into backup memory.

This output message sends out almanacs stored in the backup memory. The Almanac of a specific GNSS ID/PRN or all Almanacs of a given GNSS ID can be requested using the TXREQ input message (refer to Section 4.9: Data retransmission request (TXREQ) for details).

Table 124. **Almanac (ALMANAC)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	13 for Almanac
Response ID	DF53P	20	10	For output is always 0x0000
GNSS ID	DF06P	30	4	-
Band	DF115P	34	4	-
PRN	Refer to Table 9	38	6	-
Almanac data	-	44	360	-

Note: Bit #0 is the LSB.

Table 125. **GPS Almanac data**

Bit position	Bits	Parameters	Description
44	8	satid	The satellite number
52	16	week	The week number for the epoch
68	8	toa	Reference time almanac
76	16	e	Eccentricity
92	16	delta_i	Rate of inclination angle
108	16	omega_dot	Rate of right ascension
124	16	spare0	-
140	24	root_A	Square root of semi-major axis
164	8	spare1	-
172	24	omega_zero	Longitude of ascending node of orbit plane at weekly epoch
196	8	spare2	-
204	24	perigee	Argument of perigee
228	8	spare3	-
236	24	mean_anomaly	Mean anomaly at reference time
260	8	spare4	-
268	11	af0	Constant clock correction
279	11	af1	First order clock correction
290	1	health	Contains 1 if the satellite is unhealthy 0 if healthy
291	1	available	Contains 1 if almanac is available 0 if not
292	8	spare5	-

Note: Bit #0 is the LSB.

Table 126. **GLONASS Almanac data**

Bit position	Bits	Parameters	Description
44	8	satid	The satellite number
52	16	week	The week number for the epoch
68	8	spare0	-

Bit position	Bits	Parameters	Description
76	20	toa	Reference time almanac
96	5	n_A	Slot number (1…24)
101	5	H_n_A	Carrier frequency channel number
106	2	M_n_A	Type of satellite 00=GLONASS 01=GLONASS-M
108	10	tau_n_A	Satellite clock correction
118	15	epsilon_n_A	Eccentricity
133	7	spare1	-
140	21	t_lambda_n_A	Time of the first ascending node passage
161	11	spare2	-
172	21	lambda_n_A	Longitude of ascending node of orbit plane at almanac epoch
193	11	spare3	-
204	18	delta_i_n_A	Inclination angle correction to nominal value
222	7	delta_T_n_dot_A	Draconian period rate of change
229	7	spare4	-
236	22	delta_T_n_A	Draconian period correction
258	10	spare5	-
268	16	omega_n_A	Argument of perigee
284	1	health	Contains 1 if the satellite is unhealthy 0 if healthy
285	1	available	Contains 1 if almanac is available 0 if not
286	14	spare6	-
300	32	Tau_c	-
332	11	NA	-
343	5	N4	-
348	16	spare7	-

Note: Bit #0 is the LSB.

Table 127. Galileo Almanac data

Bit position	Bit	Parameter	Definition	Res.	unit
44	16	Sat_id	ST satellite ID	1	-
60	6	SVID	Satellite ID	1	-
66	10	Spare0	-	-	-
76	16	WN_a	Almanac reference week number	1	week
92	16	Spare1	-	-	-
108	20	t_{oa}	Almanac reference time	600	s
128	12	Spare2	--	-	-
140	13	Δ(A1/2)	Difference square root semi-major axis nominal semimajor axis	2^{-9}	$Meters^{1/2}$
153	11	e	Eccentricity	2^{-16}	-
164	8	Spare3	-	-	-
172	16	ω	Argument of perigee	2^{-15}	Semicircles
188	11	δ_i	Difference inclination angle at reference time and nominal inclination	2^{-14}	Semicircles

Bit position	Bit	Parameter	Definition	Res.	unit
199	5	Spare4	-	-	-
204	16	Ω_0	Longitude of ascending node of orbital plane at weekly epoch	2^{-15}	Semicircles
220	11	Ω	Rate of right ascension	2^{-33}	Semicircles
231	5	Spare5	-	-	-
236	16	M_0	Satellite mean anomaly at reference time	2^{-15}	Semicircles
252	16	a_{f0}	Satellite clock correction bias “truncated”	2^{-19}	s
268	13	a_{f1}	Satellite clock correction linear “truncated”	2^{-38}	s/s
281	2	E5b_HS	Satellite E5b signal health status	-	-
283	2	E1B_HS	Satellite E1-B/C signal health status	-	-
285	4	IOD_a	Almanac issue of data	-	-
289	4	IOD_a	Almanac issue of data	-	-
293	2	Reserved	Reserved for use by GNSS library	-	-
295	1	Health	Contains 1 if the satellite is unhealthy 0 if healthy.	-	-
296	2	Reserved	Reserved for use by GNSS library	-	-
298	1	Spare6	Contains 1 if the satellite is unhealthy, 0 if healthy	-	-

Note: Bit #0 is the LSB.

Table 128. BeiDou Almanac data

Bit position	Bits	Parameters	Description
44	8	prn	PRN number of the corresponding almanac data
52	16	week	Almanac reference week number
68	8	toa	Almanac reference time
76	17	eccentricity	Eccentricity
93	11	af0	Satellite clock time bias correction coefficient
104	1	is_geo	Satellite orbit type
105	1	WNa_valid	-
106	2	spare0	-
108	17	omega_dot	Rate of right ascension
125	11	af1	Satellite clock time drift correction coefficient
136	4	spare1	-
140	24	root_a	Square root of semi-major axis
164	8	spare2	-
172	24	omega_zero	Longitude of ascending node of orbital plane at weekly epoch
196	8	spare3	-
204	24	perigee	Argument of perigee
228	8	spare4	-
236	24	mean_anomaly	Mean anomaly at reference time
260	8	spare5	-
268	16	delta_i	Correction of inclination angle at reference time
284	1	Health	Satellite health information

Bit position	Bits	Parameters	Description
285	1	Available	Contains 1 if almanac is available 0 if not.
286	8	last_received_toa	-
294	6	Spare6	-

Note: Bit #0 is the LSB.

Table 129. BCNAV2 and BCNAV3 Almanac data

Bit position	Bits	Parameters	Description
44	16	omega_zero	Longitude of ascending node of orbital plane at weekly epoch
60	16	perigee	Argument of perigee
76	17	root_a	Square root of semi-major axis
93	13	WNa	Week number of the issue of data
106	2	sat_orbit_type	Satellite orbit type (1: GEO, 10: IGSO, 11: MEO, 00: reserved)
108	11	delta_i	Correction of inclination angle at reference time
119	11	af0	Satellite clock time bias correction coefficient
130	10	af1	Satellite clock time drift correction coefficient
140	16	mean_anomaly	Mean anomaly at reference time
156	8	toa	Almanac reference time
164	8	sat_health	Satellite health information (clock, B1C, B2a, …)
172	11	eccentricity	Eccentricity
183	11	omega_dot	Rate of right ascension
194	6	prn	PRN number of the corresponding almanac data
200	1	is_geo	Satellite orbit type
201	11	health	Satellite health information
212	1	available	Contains 1 if almanac is available, 0 if not
213	1	spare0	-

Note: Bit #0 is the LSB.

Table 130. NavIC (IRNSS) Almanac data

Bit position	Bits	Parameters	Description
44	10	WNa	Week number for almanac
54	16	toa	Almanac reference time
70	6	prn_al	PRN ID for Almanac

Bit position	Bits	Parameters	Description
76	16	eccentricity	Eccentricity
92	16	omega_dot	Rate of right ascension
108	24	inclination	Inclination
132	8	ISC	Inter-signal correction
140	24	root_a	Square root of the semi-major axis
164	8	spare0	-
172	24	omega_zero	Longitude of ascending node of orbit plane at weekly epoch
196	6	spare	-
202	2	spare1	-
204	24	perigee	Argument of perigee
228	6	prn	PRN ID
234	2	spare2	-
236	24	mean_anomaly	Mean anomaly at reference time
260	8	spare3	-
268	11	af0	Clock bias A0
279	11	af1	Clock drift A1
290	1	health	Contains 1 if the satellite is unhealthy, 0 if healthy
291	1	available	Contains 1 if almanac is available 0 if not.
292	8	spare4	-

Note: Bit #0 is the LSB.

Table 131. **CNAV Almanac data**

Bit position	Bits	Parameters	Description
44	8	satid	The satellite number
52	16	week	The week number for the epoch
68	8	toa	Almanac reference time
76	11	eccentricity	Eccentricity
87	21	delta_i	Rate of inclination angle.
108	11	omega_dot	Rate of right ascension.
119	21	spare0	-
140	17	root_A	Square root of semi-major axis
157	15	spare1	-
172	16	omega_zero	Longitude of ascending node of orbit plane at weekly epoch
188	16	spare2	-
204	16	perigee	Argument of perigee.
220	16	spare3	-
236	16	mean_anomaly	Mean anomaly at reference time.
252	16	spare4	-
268	11	af0	Constant clock correction.
279	10	af1	First order clock correction.
289	1	health	Contains 1 if the satellite is unhealthy 0 if healthy.
290	1	available	Contains 1 if almanac is available 0 if not.
291	9	spare5	-
300	32	spare6	-
332	32	spare7	-

Note: Bit #0 is the LSB.

4.35 Debug information message (STDBG)

The DBG message provides a message to report specific debug information data in the RTCM3 output stream.

Table 132. **Debug information (STDBG)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	35 for auxiliary message
Debug data type ID	DF114P	20	8	-
Debug data	-	28	32*N	N(1) depends on the debug data type ID

1. *The number of words N depends on the debug data type. Debug information is ST specific information.*

The debug data are encoded in 32-bit words.

4.36 Signal quality metrics 3 (SIGQM3)

This message reports the calculated signal quality metrics (SQM) and auto-correlation metrics (ACM) values in a more compact format respect to SIGQM message.

There are 2 versions of the SIGQM3 message format with metrics mask bit 31 to identify the 2 versions.

Table 133. Signal quality metrics 3 (SIGQM3) with metric mask DF22P bit 31 = 0

Data field	DF	Bit pos	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Sub type ID	DF02P	12	8	45 for signal quality metrics 3
Reference station ID	DF003	20	12	-
RFU	-	32	8	Reserved for future use
GPS epoch time (TOW)	DF004	40	30	Best time converted to GPS system time
GNSS ID	DF06P	70	4	-
GNSS satellite mask	DF07P	74	40	N= nr. of bit sets
Metrics mask	DF22P	114	32	1-bit x metric, M= nr. or bit set bit 31 = 0
Multiple message indicator	DF23P	138	1	-
Metrics value	DF56P	139	-	See Table 135. DF56P compact metrics mask (signal quality)

Table 134. Signal quality metrics 3 (SIGQM3) with metrics mask DF22P bit 31 = 1

Data field	DF	Bit pos	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Sub type ID	DF02P	12	8	45 for signal quality metrics 2
Reference station ID	DF003	20	12	-
RFU	-	32	8	Reserved for future use
GPS epoch time (TOW)	DF004	40	30	Best time converted to GPS system time
GNSS ID	DF06P	70	4	-
GNSS satellite mask	DF07P	74	40	N=nr. of bit sets
Metrics mask	DF22P	114	32	1-bit x metric, M= nr. or bit set bit 31 = 1, metrics mask 2 field added.
Metrics mask 2	DF126P	146	32	1-bit x metric, M_2= nr. or bit set
Multiple message indicator	DF23P	178	1	-
Metrics value	DF56P	179		See Table 135. DF56P compact metrics mask (signal quality) and Table 136. DF56P compact metrics mask 2 (signal quality)

Table 135. DF56P compact metrics mask (signal quality)

Bit pos	Bit in DF22P	Metrics	Band	Res.	Size (bits) in DF56P
114	0	Signal strength (CN0)	1	1 dB Hz	8 (u)
115	1	Carrier loop discriminator output std estimate [mdeg]	1	1	16 (s)
116	2	Code loop discriminator output bias estimate [cm]	1	1	16 (s)
117	3	Double-delta metric, based on 5x correlations [cm]	1	1	16 (s)
118	4	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	1	1	16 (s)
119	5	DSP flags (see Table 23. DSP flags)	1	-	32

Bit pos	Bit in DF22P	Metrics	Band	Res.	Size (bits) in DF56P
120	6	Metrics flags (see Table 22. Metrics flags field encoding)	1	-	16
121	7	Satellite elevation angle	-	1 deg.	8 (s)
122	8	DSP flags 2 (see Table 24. DSP flags 2)	1	-	32(u)
123	9	Reserved	-	-	-
124	10	Signal strength (CN0)	2	1 dB Hz	8 (u)
125	11	Carrier loop discriminator output std estimate [mdeg]	2	1	16 (s)
126	12	Code loop discriminator output bias estimate [cm]	2	1	16 (s)
127	13	Double-delta metric, based on 5x correlations [cm]	2	1	16 (s)
128	14	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	2	1	16 (s)
129	15	DSP flags (see Table 23. DSP flags)	2	-	32
130	16	Metrics flags (see Table 22. Metrics flags field encoding)	2	-	16
131	17	Reserved	-	-	
132	18	DSP flags 2 (see Table 24. DSP flags 2)	2	-	32(u)
133	19	Reserved	-	-	-
134	20	Signal strength (CN0)	3	1 dB Hz	8 (u)
135	21	Carrier loop discriminator output std estimate [mdeg]	3	1	16 (s)
136	22	Code loop discriminator output bias estimate [cm]	3	1	16 (s)
137	23	Double-delta metric, based on 5x correlations [cm]	3	1	16 (s)
138	24	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	3	1	16 (s)
139	25	DSP flags (see Table 23. DSP flags)	3	-	32
140	26	Metrics flags (see Table 22. Metrics flags field encoding)	3	-	16
141	27	Reserved	-	-	-
142	28	DSP flags 2 (see Table 24. DSP flags 2)	3	-	32(u)
143	29	Reserved	-	-	-
144	30	User1	-	-	32(u)
145	31	Metrics mask 2 enable / disable. 1 = enable, 0 = disable	-	-	-

Note: Bit0 is the LSB.

- U means unsigned
- S means signed

Table 136. DF56P compact metrics mask 2 (signal quality)

Bit pos	Bit in DF126P	Metrics	Band	Res.	Size (bits) in DF56P
146	0	Signal strength (CN0)	4	1 dB Hz	8 (u)
147	1	Carrier loop discriminator output std estimate [mdeg]	4	1	16 (s)
148	2	Code loop discriminator output bias estimate [cm]	4	1	16 (s)
149	3	Double-delta metric, based on 5x correlations [cm]	4	1	16 (s)

Bit pos	Bit in DF126P	Metrics	Band	Res.	Size (bits) in DF56P
150	4	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	4	1	16 (s)
151	5	DSP flags (see Table 23. DSP flags)	4	-	32
152	6	Metrics flags (see Table 22. Metrics flags field encoding)	4	-	16
153	7	Reserved	-	-	-
154	8	DSP flags 2 (see Table 24. DSP flags 2)	4	-	32 (u)
155	9	Reserved	-	-	-
156	10	Signal strength (CN0)	5	1 dB Hz	8 (u)
157	11	Carrier loop discriminator output std estimate [mdeg]	5	1	16 (s)
158	12	Code loop discriminator output bias estimate [cm]	5	1	16 (s)
159	13	Double-delta metric, based on 5x correlations [cm]	5	1	16 (s)
160	14	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	5	1	16 (s)
161	15	DSP flags (see Table 23. DSP flags)	5	-	32
162	16	Metrics flags (see Table 22. Metrics flags field encoding)	5	-	16
163	17	Reserved	-	-	-
164	18	DSP flags 2 (see Table 24. DSP flags 2)	5	-	32 (u)
165	19	Reserved	-	-	-
166	20	Signal strength (CN0)	6	1 dB Hz	8 (u)
167	21	Carrier loop discriminator output std estimate [mdeg]	6	1	16 (s)
168	22	Code loop discriminator output bias estimate [cm]	6	1	16 (s)
169	23	Double-delta metric, based on 5x correlations [cm]	6	1	16 (s)
170	24	Auto-correlation metric #1, based on 10x correlations (parameter added when 1 or more pools are enabled in CDB [P16, L02, F05])	6	1	16 (s)
171	25	DSP flags (see Table 23. DSP flags)	6	-	32
172	26	Metrics flags (see Table 22. Metrics flags field encoding)	6	-	16
173	27	Reserved	-	-	-
174	28	DSP flags 2 (see Table 24. DSP flags 2)	6	-	32 (u)
175	29	Reserved	-	-	-
176	30	User2	-	-	32 (u)
177	31	Reserved	-	-	-

Note: Bit0 is the LSB.

Note:

1. *For the size column, (u) means unsigned and (s) means signed.*
2. *For unsigned 8-bit fields the 0xFF value means NOT VALID.*
3. *For signed 8-bit fields the 0x80 value means NOT VALID.*
4. *For unsigned 16-bit fields the 0xFFFF value means NOT VALID.*
5. *For signed 16-bit fields the 0x7FFF value means NOT VALID. In case of Double-Delta metric and Auto-Correlation metric, if their values exceed the signed 16-bit representation limits, it saturates to 32767 (for positive values) or -32768 (for negative values).*
6. *For unsigned 32-bit fields the 0xFFFFFFFF value means NOT VALID.*
7. *For signed 32-bit fields the 0x7FFFFFFF value means NOT VALID.*

4.37 Observable quality metrics 2 (OBSQM2)

This message reports the calculated observable quality metrics (OBSQM) values.
There are 2 versions of the OBSQM2 message format with metrics mask bit 31 to identify the 2 versions.

Table 137. Observable quality metrics 2 (OBSQM2) with metrics mask bit 31=0

Data field	DF	Bit pos	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Sub type ID	DF02P	12	8	46 for observable quality metrics 2
Reference station ID	DF003	20	12	-
RFU	-	32	8	Reserved for future use
GPS epoch time (TOW)	DF004	40	30	Best time converted to GPS system time
GNSS ID	DF06P	70	4	-
GNSS satellite mask	DF07P	74	40	N=nr. of bit sets
Metrics mask	DF22P	114	32	1-bit x metric, M=nr. or bit set bit 31 = 0
Multiple message indicator	DF23P	146	1	-
Metrics value	DF24P	147	32	N*M elements

Table 138. Observable quality metrics 2 (OBSQM2) with metrics mask bit 31=1

Data field	DF	Bit pos	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Sub type ID	DF02P	12	8	46 for observable quality metrics
Reference Station ID	DF003	20	12	
RFU	-	32	8	Reserved for future use
GPS epoch time (TOW)	DF004	40	30	Best time converted to GPS system time
GNSS ID	DF06P	70	4	
GNSS satellite mask	DF07P	74	40	N=nr. of bit sets
Metrics mask	DF22P	114	32	1-bit x metric, M=nr. or bit set bit 31 = 1, metrics mask 2 field added.
Metrics mask 2	DF22P	146	32	1-bit x metric, M_2=nr. or bit set
Multiple message indicator	DF23P	178	1	
Metrics value	DF24P	179	32	N*(M+M_2) elements

Table 139. DF22P metrics mask (observable quality)

Bit pos	Bit	Metrics	Band	Res.
114	0	Code-carrier divergence (main freq.)	1	1
115	1	Code-carrier divergence (dual freq.)	2	1
116	2	Code-carrier divergence (triple freq.)	3	1
117	3	Doppler to range-rate divergence (main freq.)	1	1

Bit pos	Bit	Metrics	Band	Res.
118	4	Doppler to range-rate divergence (dual freq.)	2	1
119	5	Doppler to range-rate divergence (triple freq.)	3	1
120	6	Dual frequency carrier phase delta gradient (main, dual)	1,2	1
121	7	Dual frequency carrier phase delta gradient (main, triple)	1,3	1
122	8	Inter frequency code bias residual (main, dual)	1,2	1
123	9	Inter frequency code bias residual (main, triple)	1,3	1
124	10	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (main)	1	1
125	11	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (dual)	2	1
126	12	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (triple)	3	1
127	13	Carrier phase pseudorange diff (main freq.)	1	1
128	14	Carrier phase pseudorange diff (dual freq.)	2	1
129	15	Carrier phase pseudorange diff (triple freq.)	3	1
130	16..30	Reserved	-	-
145	31	Metrics mask 2 enable / disable. 1 = enable, 0 = disable	-	-

Note: Bit0 is the LSB.

Table 140. DF22P metrics mask 2 (observable quality)

Bit pos	Bit	Metrics	Band	Res.
146	0	Code-carrier divergence (F4)	4	1
147	1	Code-carrier divergence (F5)	5	1
148	2	Code-carrier divergence (F6)	6	1
149	3	Doppler to range-rate divergence (F4)	4	1
150	4	Doppler to range-rate divergence (F5)	5	1
151	5	Doppler to range-rate divergence (F6)	6	1
152	6	Dual-frequency carrier phase delta gradient (F1, F5)	1, 5	1
153	7	Dual-frequency carrier phase delta gradient (F1, F6)	1, 6	1
154	8	Inter-frequency code bias residual (F1, F5)	1, 5	1
155	9	Inter-frequency code bias residual (F1, F6)	1, 6	1
156	10	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F4)	4	1
157	11	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F5)	5	1
158	12	Pseudorange (uint12), carrier phase (uint10) and doppler (uint10) STD (F6)	6	1
159	13	Carrier phase pseudorange diff (F4)	4	1
160	14	Carrier phase pseudorange diff (F5)	5	1
161	15	Carrier phase pseudorange diff (F6)	6	1
162	16	Dual-frequency carrier phase delta gradient (F1, F4)	1, 4	1
163	17	Inter-frequency code bias residual (F1, F4)	1, 4	1
164	18..31	reserved	-	-

Note: Bit0 is the LSB.

0x7FFFFFFF means saturation/not valid for metrics code carrier divergence, doppler to range rate divergence, dual frequency carrier phase delta gradient, inter frequency code bias residual.

Pseudorange, carrier phase and doppler STD are encoded on a single 32-bit word for each band. The bits #31 to #20 represent the pseudorange STD (0xFFF means saturation/not valid), the bits #19 to #10 represent the carrier phase STD (0x3FF means saturation/not valid), and the bits #9 to #0 represent the doppler STD (0x3FF means saturation/not valid). Refer to Table 21. Signals position for signal position from the GNSS system.

4.38 GNSS OSNMA (STNMA)

This input message allows the user to configure OSNMA. A RESP message is sent when done if the response ID is not zero.

This output message sends an OSNMA configuration, it can be requested using the TXREQ input message (see Section 4.9: Data retransmission request (TXREQ) for details).

Table 141. Proprietary RTCM3 STNMA messages

Msg number	Subtype ID	STNMA type ID	Description	Direction
ST proprietary ID	14	0	NVM invalidate	in
		1	Status on/off	in/out
		2	Reserved	-
		3	Reserved	-
		4	TSL	in
		5	MACSEQ flags	in
		6	PK	in
		7-10	Reserved	-
		11	Get public keys (GETPK)	out
		12	Clear public key (CLRPK)	in
		13	Set Merkle tree (SETMTR)	in
		14	Get merkle tree roots (GETMTR)	out
		15	Clear Merkle tree (CLRMTR)	in
		16	Set Intermediate tree nodes (SETITN)	in
		17	Get intermediate tree nodes	out
		18	Clear intermediate tree node (CLRITN)	in
		19	Clear OSNMA Alert Message (CLRAM)	in
		20	Clear OSNMA root key (CLRKROOT)	in
		22	Get DSM blocks (GETDSM)	out
		23	Set DSM blocks (SETDSM)	in

Table 142. GNSS OSNMA (STNMA) message header

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	14 for STNMA
Response ID	DF53P	20	10	For output is always 0x0000
STNMA type ID	DF116P	30	6	(Refer to Table 141. Proprietary RTCM3 STNMA messages).

Note: Bit#0 is the LSB.

4.38.1 NVM invalidate (NVM_INV)

Clear the OSNMA keys stored in the NVM database. A system reset is advised for the change to take effect. A RESP message is sent when it is done.

4.38.2 Status (STATUS)

Set enable/disable the use of OSNMA authenticated satellites only for fix and a RESP message is sent when it is done.

Allow the use of OSNMA authenticated satellites only for fix.

Table 143. Status (STATUS)

Data field	DF	Bit position	Bits	Notes
Status fix authenticated only	DF117P	36	uint1	-

Note: Bit# 0 is the LSB.

4.38.3 Target security level (TSL)

Set the minimum security level for OSNMA authentication.

Table 144. Target security level (TSL)

Data field	DF	Bit position	Bits	Notes
TSL	-	36	uint16	Minimum security level

Note: Bit #0 is the LSB.

4.38.4 MACSEQ flags (MACSEQ_FLAGS)

Set enable/disable the verification of the MAC sequence during the authentication process.

Table 145. MACSEQ flags (MACSEQ_FLAGS)

Data field	DF	Bit position	Bits	Notes
MACSEQ flags	-	36	32	MACSEQ feature options flags Bit #0 = feature enable (1=ON, 0 = OFF)

Note: Bit #0 is the LSB.

4.38.5 Public key (PK)

Set OSNMA ECDSA public key at a special index and save it in NVM.

Table 146. Public key (PK)

Data Field	DF	Bit pos	Bits	Notes
Message ID	-	36	4	Message ID (MID) from 0 to 15.
Key index	-	40	4	Key index from 0 to 15
Reserved	-	44	4	-
Public key	-	48	264 or 536	ECDSA public key.

Note: Bit#0 is the LSB.

4.38.6 Get public keys (GETPK)

Get all public keys stored in NVM.

Table 147. Get public keys (GETPK)

Data field	DF	Bit pos	Bits	Notes
PK retrieving error bitmap	-	36	16	Each bit set to 1 in this bitmap means that PK with ID equal to the bit rank couldn't be retrieved from NVM
Available keys bitmap	-	52	16	Each bit set to 1 in this bitmap represents a PK with ID equal to the bit rank
MID	-	68	4	MID of the first PK in the bitmap
PK type	-	72	4	Type of the first PK in the bitmap • 1 = ECDSA P-256 • 3 = ECDSA P-521
PK	-	76	264 or 536	Public key (size according to type)

Note: MID, PK type and PK data fields are repeated for each key present in the available keys bitmap.

4.38.7 Clear public key (CLRPK)

Table 148. Clear public key (CLRPK)

Data field	DF	Bit pos	Bits	Notes
PK ID	-	36	4	ID of the public key to clear

4.38.8 Set Merkle tree root (SETMTR)

Set Merkle tree root and save it in NVM

Table 149. Set Merkle tree root parameters (SETMTR)

Data field	DF	Bit position	Bits	Notes
mtr_id	-	36	1	Merkle tree root index Bit #0: 0 = current 1 = future
sha_type	-	37	1	Bit #0: 0 = sha-256 1 = sha-512
mtr_data	-	38	256	Merkle tree root value

Note: Bit #0 is the LSB.

4.38.9 Get merkle tree roots (GETMTR)

Get all merkle tree roots stored in NVM.

Table 150. Get merkle tree roots (GETMTR)

Data field	DF	Bit pos	Bits	Notes
Available MTR bitmap	-	36	2	Each bit set to 1 in this bitmap represents a MTR. Bit 0 for present MTR and bit 1 for future MTR

Data field	DF	Bit pos	Bits	Notes
MTR SHA type	-	38	1	0 = SHA-256 1 = SHA-512
MTR	-	39	256	Merkle tree root

Note: MTR SHA type and MTR data fields are repeated for each MTR present in the available MTR bitmap.

4.38.10 Clear Merkle tree root (CLRMTR)

Clear Merkle tree root.

Table 151. Clear Merkle tree root parameters (CLRMTR)

Data field	DF	Bit position	Bits	Notes
mtr_id	-	36	1	Merkle tree root index Bit #0: 0 = current 1=future

Note: Bit #0 is the LSB.

4.38.11 Set intermediate tree nodes (SETITN)

Set intermediate tree nodes data for levels 0 to 3 and save them in NVM.

Table 152. Set intermediate tree nodes parameters (SETITN)

Data field	DF	Bit position	Bits	Notes
itn_node0	-	36	256	Intermediate tree node data level 0
itn_node1	-	292	256	Intermediate tree node data level 1
itn_node2	-	548	256	Intermediate tree node data level 2
itn_node3	-	804	256	Intermediate tree node data level 3

Note: Bit #0 is the LSB.

4.38.12 Get intermediate tree nodes (GETITN)

Get all intermediate tree nodes stored in NVM.

Table 153. Get intermediate tree nodes (GETITN)

Data field	DF	Bit pos	Bits	Notes
Error	-	36	1	0 = No error 1 = An error occurred during ITN retrieving
ITN 0	-	37	256	ITN level 0
ITN 1	-	293	256	ITN level 1
ITN 2	-	549	256	ITN level 2
ITN 3	-	805	256	ITN level 3

Note: If error is 1, then the message stops after and the 4 ITN aren't output.

4.38.13 Clear intermediate tree (CLRITN)

Clear intermediate tree node level j.

Table 154. Clear intermediate tree node parameter (CLRITN)

Data field	DF	Bit position	Bits	Notes
j	-	36	2	Intermediate tree node level j (0 to 3)

Note: Bit #0 is the LSB.

4.38.14 Clear alert message (CLRAM)

Clear OSNMA alert message state.

4.38.15 Clear root key (CLRKROOT)

Clear OSNMA root key stored in NVM. This command is used to perform OSNMA warm start. A reset is needed.

4.38.16 Get DSM blocks (GETDSM)

Get all DSM blocks stored in NVM.

Table 155. Get DSM blocks (GETDSM)

Data field	DF	Bit pos	Bits	Notes
DSM-KROOT ID	-	36	int5	ID in [0-11], -1 if unknown
Available blocks bitmap	-	41	16	Each bit equal to 1 represents one block with ID equal to the bit rank
DSM-KROOT blocks	-	57	(nb of DSM-KROOT blocks)*120	Content of all blocks reported by the bitmap
DSM-PKR ID	-	57+ (nb of DSM-KROOT blocks)*120	5	ID in [12-15], -1 if unknown
Available blocks bitmap	-	57 + (nb of DSM-KROOT blocks)*120 + 5	16	Each bit equal to 1 represents one block with ID equal to the bit rank
DSM-PKR blocks	-	57 + (nb of DSM-KROOT blocks)*120 + 5 + 16	(nb of DSM-PKR blocks)*120	Content of all blocks reported by the bitmap

Note: If a bitmap is equal to 0, then the following part containing blocks is empty.

4.38.17 Set DSM blocks (SETDSM)

Set DSM blocks.

Table 156. Set DSM blocks (SETDSM)

Data field	DF	Bit pos	Bits	Notes
DSM-KROOT ID	-	36	4	ID in [0-11]
Available blocks bitmap	-	40	16	Each bit equal to 1 represents one block with ID equal to the bit rank
DSM-KROOT blocks	-	56	(nb of DSM-KROOT blocks)*120	Content of all blocks reported by the bitmap
DSM-KROOT ID	-	56+(nb of DSM-KROOT blocks)*120	4	ID in [12-15]
Available blocks bitmap	-	56+(nb of DSM-KROOT blocks)*120+4	16	Each bit equal to 1 represents one block with ID equal to the bit rank

Data field	DF	Bit pos	Bits	Notes
DSM-PKR blocks	-	56+(nb of DSM-KROOT blocks)*120+4+16	(nb of DSM-PKR blocks)*120	Content of all blocks reported by the bitmap

Note: If a DSM is unknown, a valid ID must be set with an empty bitmap.

4.39 GNSS OSNMA event (STNMAEVT)

This output message sends OSNMA event information.

Table 157. Proprietary RTCM3 STNMAEVT messages

Msg number	Subtype ID	STNMAEVT type ID	Description	Direction
ST proprietary ID	36	7	MACV event	Out
		8	DSMV event	Out
		9	PKRV event	Out
		10	Alert message event	Out
		21	NMA status	Out

Table 158. GNSS OSNMA (STNMAEVT) message header

Data field	DF	Bit pos	Bits	Notes
Message Number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	36 for STNMA event
STNMA type ID	DF116P	20	6	(Refer to Table 157)

Note: Bit #0 is the LSB.

4.39.1 MACV event (MACV)

OSNMA output event MACV that reports the MAC authentication status.

Table 159. MACV event (MACV)

Data field	DF	Bit position	Bits	Notes
result	-	26	int8	0 = MAC authentic 1 = MAC not authentic (-1) = no input data (-2) = processing error during MAC ver. (-3) = removed because of max. age (-7) = slow MAC filtered (-10) = MACLT ADKD check failed (-14) = FLX with MAC0 not available (-15) = one or more FLX missing (-17) = MACSEQ not authentic (-19) = MACLT index not available (-20) = processing error during MACSEQ
slc	-	34	int16	Security level counter (MAC accumulation)
gst v tow	-	50	uint30	Time of verification
gst v week number	-	80	uint16	Week number of verification

Data field	DF	Bit position	Bits	Notes
cpu time v	-	96	uint32	Cpu time of verification
cpu time r	-	128	uint32	Time of reception of the last bit of the MAC
cpu time d	-	160	uint32	Time of reception of the last bit of the data to authenticate
prn a	-	192	uint8	Identifies the satellite transmitting the authentication information. Galileo satellite.
prn	-	200	uint8	Authenticated PRN (for MAC0, PRN_N is filled with PRN_A), in the case, this field is set to the value “255”, PRN = PRN A
adkb or macseq	-	208	uint16	If MAC0 (blk_idx=0, ctr=1), MAC sequence that allows the receiver to authenticate the tag-info field for the tags whose ADKD type is identified as flexible within the MAC look-up Table. If not MAC0, authentication data & key delay describes the authenticated navigation data, used to generate the associated tag.
cop	-	224	uint8	Cut-Off point
ctr	-	232	uint8	Position of the tag within the MACK message
mac64	-	240	uint64	MacInfo or authentication tag.
nma status	-	304	uint2	NMA status NMAS / Definition / Semantic 0 / Reserved / - 1 / Test / OSNMA is provided without any operational guarantees. 2 / Operational / OSNMA is provided according to the specifications. 3 / Do not use / Navigation data shall not be authenticated with the provided OSNMA information.
cid	-	306	uint8	Chain ID represents the ID of the key chain in force. Values from 0 to 3.
cpks	-	314	uint3	Chain and public key status, provides the status of the key chain and public key in force. Values 0 to 7
gst tow	-	317	uint30	TOW GST of the subframe containing the MAC
gst week number	-	347	uint16	WN GST of the subframe containing the MAC

Note: Bit #0 is the LSB.

4.39.2 DSMV event (DSMV)

OSNMA output event DSMV that reports the DSM KROOT validation status.

Table 160. DSMV event (DSMV)

Data field	DF	Bit position	Bits	Notes
result	-	26	int8	0 = Authentic 1 = Not authentic 2 = PK not available
gst v tow	-	34	uint30	Time of verification

<table>
<tr><th>Data field</th><th>DF</th><th>Bit position</th><th>Bits</th><th>Notes</th></tr>
<tr><td>gst v week number</td><td>-</td><td>64</td><td>uint16</td><td>Week number of verification</td></tr>
<tr><td>cpu time v</td><td>-</td><td>80</td><td>uint32</td><td>Receiver clock counter at validation epoch</td></tr>
<tr><td>dsm_id</td><td>-</td><td>112</td><td>uint8</td><td>Digital signature message ID associated with the current block.
0...11 = for DSM-KROOT</td></tr>
<tr><td>nma status</td><td>-</td><td>120</td><td>uint2</td><td>NMA status
<table>
<tr><th>NMAS</th><th>Definition</th><th>Semantic</th></tr>
<tr><td>0</td><td>Reserved</td><td>-</td></tr>
<tr><td>1</td><td>Test</td><td>OSNMA is provided without any operational guarantees.</td></tr>
<tr><td>2</td><td>Operational</td><td>OSNMA is provided according to the specifications.</td></tr>
<tr><td>3</td><td>Do not use</td><td>Navigation data shall not be authenticated with the provided OSNMA information.</td></tr>
</table></td></tr>
<tr><td>cid</td><td>-</td><td>122</td><td>uint2</td><td>Chain ID represents the ID of the key chain in force. Values from 0 to 3.</td></tr>
<tr><td>cpks</td><td>-</td><td>124</td><td>uint3</td><td>Chain and public key status, provides the status of the key chain and public key in force. Values 0 to 7</td></tr>
<tr><td>num blocks</td><td>-</td><td>127</td><td>uint8</td><td>Number of DSM KROOT blocks</td></tr>
<tr><td>pk id</td><td>-</td><td>135</td><td>uint8</td><td>ID of the public key (PK) used to verify the signature of the DSM-KROOT.</td></tr>
<tr><td>cid kr</td><td>-</td><td>143</td><td>uint8</td><td>KROOT chain ID identifies the chain to which the signed KROOT belongs.</td></tr>
<tr><td>res1</td><td>-</td><td>151</td><td>uint8</td><td>Reserved1 field as described in OSNMA ICD</td></tr>
<tr><td>HF</td><td>-</td><td>159</td><td>uint8</td><td>Hash function used for the chain:
0 SHA-256
1 reserved
2 SHA3-256
3 reserved</td></tr>
<tr><td>MF</td><td>-</td><td>167</td><td>uint8</td><td>The MAC function used to authenticate the navigation data:
0 = HMAC-SHA-256
1 = CMAC-AES
2-3 = reserved</td></tr>
<tr><td>KS</td><td>-</td><td>175</td><td>uint8</td><td>Key size identifies the entry of a look-up table indicating the length l_k of the keys of the chain, expressed in bits.</td></tr>
</table>

<table>
<tr><th>Data field</th><th>DF</th><th>Bit position</th><th>Bits</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td><td></td><td><table><tr><th>KS</th><th>Key length</th></tr><tr><td>0</td><td>96</td></tr><tr><td>1</td><td>104</td></tr><tr><td>2</td><td>112</td></tr><tr><td>3</td><td>120</td></tr><tr><td>4</td><td>128</td></tr><tr><td>5</td><td>160</td></tr><tr><td>6</td><td>192</td></tr><tr><td>7</td><td>224</td></tr><tr><td>8</td><td>256</td></tr><tr><td>9-15</td><td>reserved</td></tr></table></td></tr>
<tr><td>TS</td><td>-</td><td>183</td><td>uint8</td><td>Tag size identifies the entry of a look-up table indicating the tags length l_t, expressed in bits.<table><tr><th>TS</th><th>Tag length</th></tr><tr><td>0-4</td><td>reserved</td></tr><tr><td>5</td><td>20</td></tr><tr><td>6</td><td>124</td></tr><tr><td>7</td><td>28</td></tr><tr><td>8</td><td>32</td></tr><tr><td>9</td><td>40</td></tr><tr><td>10-15</td><td>reserved</td></tr></table></td></tr>
<tr><td>maclt</td><td>-</td><td>191</td><td>uint8</td><td>MAC look-up table</td></tr>
<tr><td>res2</td><td>-</td><td>199</td><td>uint8</td><td>Reserved2 field as described in OSNMA ICD</td></tr>
<tr><td>kr wn</td><td>-</td><td>207</td><td>uint16</td><td>KROOT week number</td></tr>
<tr><td>kr towh</td><td>-</td><td>223</td><td>uint8</td><td>KROOT time of week</td></tr>
</table>

Note: Bit #0 is the LSB.

4.39.3 PKRV event (PKRV)

OSNMA output event PKRV that reports the DSM-PKR validation status.

Table 161. PKRV event (PKRV)

Data field	DF	Bit position	Bits	Notes
result	-	26	int8	0 = Verified 1 = Not verified
mtr_id	-	34	int8	Merkle tree root index: • 0 = current • 1 = future • -1 = if both failed (in that case the result is not 0)
gst v tow	-	42	uint30	TOW GST of the subframe containing the MAC
gst v week number	-	72	uint16	Week number GST of the subframe containing the MAC

<table>
<tr><th>Data field</th><th>DF</th><th>Bit position</th><th>Bits</th><th>Notes</th></tr>
<tr><td>cpu time v</td><td>-</td><td>88</td><td>uint32</td><td>Cpu time of verification</td></tr>
<tr><td>dsm_id</td><td>-</td><td>120</td><td>uint8</td><td>Digital signature message ID associated with the current block.
12 to 15 = for DSM-PKR</td></tr>
<tr><td>nma status</td><td>-</td><td>128</td><td>uint2</td><td>NMA status
<table><tr><th>NMAS</th><th>Definition</th><th>Semantic</th></tr><tr><td>0</td><td>Reserved</td><td>-</td></tr><tr><td>1</td><td>Test</td><td>OSNMA is provided without any operational guarantees.</td></tr><tr><td>2</td><td>Operational</td><td>OSNMA is provided according to the specifications.</td></tr><tr><td>3</td><td>Do not use</td><td>Navigation data shall not be authenticated with the provided OSNMA information.</td></tr></table></td></tr>
<tr><td>cid</td><td>-</td><td>130</td><td>uint2</td><td>Chain ID represents the ID of the key chain in force. Values from 0 to 3.</td></tr>
<tr><td>cpks</td><td>-</td><td>132</td><td>uint3</td><td>Chain and public key status, provides the status of the key chain and public key-in force. Values 0 to 7</td></tr>
<tr><td>num blocks</td><td>-</td><td>135</td><td>uint8</td><td>Number of blocks of the DSM-PKR in the I/NAV subframe.</td></tr>
<tr><td>mid</td><td>-</td><td>143</td><td>int8</td><td>Message ID identifies which leaf of the Merkle tree is provided</td></tr>
<tr><td>npkt</td><td>-</td><td>151</td><td>int8</td><td>The new public key type represents the signature algorithm associated with the public key provided in the DSM-PKR:
• 1 = ECDSA P-256
• 3 = ECDSA P-521
• Other = reserved</td></tr>
<tr><td>npkid</td><td>-</td><td>159</td><td>int8</td><td>New public key ID</td></tr>
</table>

Note: Bit #0 is the LSB.

4.39.4 Alert message event

OSNMA outputs an event alert message broadcasted by satellites.

Table 162. Alert event (ALERT)

Data field	DF	Bit position	Bits	Notes
cpu time	-	26	uint32	-
dsm_id	-	58	uint4	-
authenticated	-	62	uint1	-
message	-	63	0 to 78 uint8	Message string

Note: Bit #0 is the LSB.

NMA status event.

OSNMA outputs this message at 1Hz to report the status of OSNMA process.

Table 163. **NMA status event (NMA_STATUS)**

Data field	DF	Bit position	Bits	Notes
NMA lib status flag	-	26	-	0 = OSNMA disabled 1 = OSNMA enabled
oam flag	-	27	-	OSNMA under alert flag 0 = no alert 1 = OSNMA under alert
DSM-KROOT ID	-	28	-	ID in [0, 11] -1 if unknown
DSM-KROOT NB	-	33	-	ID in [0, 16]. 0 means unknown
DSM-KROOT bitmap	-	38	-	Bitmap representing the downloaded DSM-KROOT blocks
DSM-PKR ID	-	54	-	ID in [0, 11] -1 if unknown
DSM-PKR NB	-	59	-	ID in [0, 16]. 0 means unknown
DSM-PKR bitmap	-	64	uint16	Bitmap representing the downloaded DSM-PKR blocks

4.40 OSNMA authenticated active satellites (STASA)

This OSNMA output message reports the signal availability and accuracy of authenticated position.

Table 164. **OSNMA authenticated active satellites (STASA)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	37 for STASA
GPS epoch time (TOW)	DF004	20	30	Best time converted to GPS system time
GNSS ID	DF06P	50	4	-
Mode	-	54	1	0 = manual, forced to operate in 2D or 3D mode 1 = automatic, allowed to automatically switch 2D/3D
Fix mode	-	55	2	1 = Fix not available, 2 = 2D, 3 = 3D
Band mask	-	57	4	Bit #0 = band 1 available Bit #1 = band 2 available Bit #2 = band 3 available Bit #3 = RFU M is the number of bits set in the mask
HDOP	DF30P	61	8	0-25.4 Invalid = 0xFF
VDOP	DF30P	69	8	0-25.4 Invalid = 0xFF
PDOP	DF30P	77	8	0-25.4 Invalid = 0xFF

Data field	DF	Bit position	Bits	Notes
Multiple message indicators	DF23P	85	1	-
Field values	-	86	40 * M	Refer to Table 165

Note: Bit #0 is the LSB.

Table 165. STASA field value

Data field	DF	Bit position	Bits	Notes
GNSS satellite mask	DF07P	86+40 * i (i in 0 to M-1)	40	Each bit is equal to 1 if the corresponding satellites is used in the solution.

Note: Satellite ID #1 is the MSB.

Refer to Table 17. Signal quality metrics 2 (SIGQM2) with metric mask DF22P bit 31 = 0 for signal position from the GNSS system.

4.41 OSNMA authenticated minimum specific data (STAMC)

This OSNMA output message reports the authenticated minimum specific data (STAMC), which contains the position information, time and speed over ground plus additional values.

Table 166. OSNMA authenticated minimum specific data (STAMC)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	21 for extended PVT
Reference station ID	DF003	20	12	Invalid = 0x3FF
ITRF realization year	DF021	32	6	Reserved for future use Must be set to invalid = 0x3F
GPS quality indicator (fix status)	DF28P	38	4	$--GGA (0 = Fix not available or invalid)
Data status (RMC A/V field)	-	42	1	0 = data valid, 1 = navigation receiver warning
Time ID	DF72P	43	4	Time ID Not valid = 0xF
Time validity	DF87P	47	4	-
GNSS epoch time	DF16P	51	30	1 ms resolution Not valid = 0x3FFFFFFF
Extended week number	DF18P	81	16	incl. roll-over The field is not valid if the GNSS epoch time is set to 0x3FFFFFFF: in such case 0xFFFF will be reported.
Leap seconds, GPS-UTC	DF054	97	8	Mark as 0xFF for not-valid/not-provided
Latitude	DF73P	105	32	0.001 [arcsec] $--GGA 0x80000000 = not valid
Longitude	DF74P	137	32	0.001 [arcsec] $--GGA 0x80000000 = not valid
Height	DF120P	169	21	0.1 [m] steps. Height from mean-sea-level (geoid)

Data field	DF	Bit position	Bits	Notes
Velocity horizontal	DF76P	190	20	0.01 [m/s] 0x80000 = not valid
Velocity vertical	DF77P	210	20	0.01 [m/s] 0x80000 = not valid
Course angle	DF78P	230	16	0.1 [deg] 0 to 3599 = valid course angle. 0x8000 = not valid. Other values not valid
Reserved	-	246	4	-

Note:
1. *In the case "GPS quality indicator (fix status)" is 0, then the following fields are not valid, regardless of their reported values:*
   - *Geoidal separation, meters*
   - *Latitude*
   - *Longitude*
   - *Height*
   - *Velocity horizontal*
   - *Velocity vertical*
   - *Course angle*
2. *In the case of 2D fix, the Height field is set to not valid (0x80000).*

4.42 Init position (INITPOS)

This message initializes the GPS position.

Table 167. Init position (INITPOS)

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID
Subtype ID	DF02P	12	8	41 for Init position
Response ID	DF53P	20	10	-
Latitude	DF73P	30	32	Latitude in step of 0.001 [arcsec] From -324000" to 324000"
Longitude	DF74P	62	32	Longitude in step of 0.001 [arcsec] From -648000" to 648000"
Height	DF75P	94	21	Height in step of 0.1 [m] (-1500 m to 100000 m) on 21 bits when FW config P22L8F1 = 1

Note: Bit #0 is the LSB.

Note: If the response ID field is different from 0x0000, then a response message is requested. In such case, the value of the response can be interpreted according to Table 1. GNSS metrics.

4.43 Time and global information (TG)

This message reports time and global information.

Table 168. **Time and global information (TG)**

Data field	DF	Bit position	Bits	Notes
Message number	DF002	0	12	ST proprietary ID (4050)
Subtype ID	DF02P	12	8	44 for time and global Information
GPS ext. week number	DF18P	20	16	Integer number of weeks since time reference
GPS epoch time (TOW)	DF004	36	30	Time of the Week in seconds
CPU time	-	66	32	CPU time in CPU ticks
Time best validity	DF87P	98	4	Best constellation time validity
NCO clock drift	-	102	32	Clock drift from tracker in 0.0001 Hz
Clock bias	-	134	32	Accurate estimated clock bias in meters
MTB time	-	166	32	GNSS master time in ms since time reference
MTB timestamp	-	198	32	GNSS master timestamp fractional precision in ps

5 MTI configuration

It is possible to configure the MTI value for each class of messages by using the firmware configuration. In the firmware configurator page 22, the lines 0, 1, 2, 3 and 4 have been reserved for that purpose.

On each line eight MTI groups are encoded, with the group with lower index encoded on the four least significant bits of such word.

The MTIs are therefore encoded on 4 bits for each class of message. The encoding of the 4 bits is the following (in seconds):

Table 169. MTI encoding

Encoding (hex)	Value (s)
0x0	When available
0x1	1
0x2	2
0x3	3
0x4	4
0x5	5
0x6	10
0x7	20
0x8	30
0x9	60
0xA	120
0xB	180
0xC	300
0xD	RFU
0xE	RFU
0xF	Disabled

The following groups of MTIs have been defined:

Table 170. MTI group IDs

MTI group ID	Message IDs are included in the group	Comment
0	Legacy observations messages (1002, 1010)	Not available on Teseo APP2
1	MSM7 observations messages (1077, 1087, 1097, 1117, 1127, 1137)	-
2	Ephemeris and additional messages (1019, 1020, 1041, 1042, 1044, 1046, 1006, 1013)	Message 1006 is not available on Teseo APP2
3	Navigation data frame (NDF) message	-
4	Receiver safety status (RSS), time and global information (TG)	-
5	Receiver configuration and control (RCC)	-
6	Almanac (ALMANAC)	-
7	Sensor message (SENS)	-
8	Reserved	-
9	Position quality metrics (POSQM)	-
10	Observable quality metrics 1 & 2 (OBSQM, OBSQM2)	-

MTI group ID	Message IDs are included in the group	Comment
11	Datum reference (STDTM)	-
12	GLONASS inter-channel Bias (ICB)	-
13	Inter-frequency bias (IFB)	-
14	Ionospheric model Parameters (IONOPAR)	-
15	Response message (RESP)	-
16	Auxiliary message (AUX)	-
17	Firmware version (FWVER)	-
18	RF Status (RFS), RF AGC (RFAGC)	-
19	TXREQ response	-
20	SIGQM2, SIGQM3	-
21	Extended PVT (EPVT) and OSNMA authenticated minimum specific data (STAMC)	-
22	Inter-frequency Bias Data (IFBDATA)	-
23	GNSS satellites in view (STGSV)	-
24	GNSS DOPs and active satellites (STGSA) and OSNMA authenticated active satellites (STASA)	-
25	GNSS RAIM parameters (STGBS)	-
26	Pseudorange error statistics (STGST)	-
27	GNSS range residuals (STGRS)	-
28	GNSS prediction ephemeris (STGPE)	Not available on Teseo APP2
29	Debug information message (STDBG)	-
30	GNSS OSNMA (STNMA) GNSS OSNMA event (STNMAEVT)	-
31	SSR Orbit correction (1057, 1240, 1258)	Not available on Teseo APP2
32	SSR clock correction (1058, 1241, 1259)	Not available on Teseo APP2
33	SSR satellite code bias (1059, 1242, 1260)	Not available on Teseo APP2

To change the MTI configuration the RCC message can be used.

Note:

- *The observation legacy messages included in the group 0 are not compatible with the MSM messages included in the group 1, so if group 0 is enabled then group 1 must be disabled and vice versa.*
- *For MTI group ID 2 ephemeris and additional messages, the MTI of ephemeris messages (1019, 1020, 1041, 1042, 1044, 1046) could be between the MTI and MTI + one epoch time. Ephemeris messages can be sent on multiple epoch.*
- *For the MTI group 0 and 1only the MTI value of 0x0 and 0xF is allowed, as specified in the following table:*

Table 171. MTI encoding for ID 0 and 1

Encoding (hex)	Value (s)
0x0	When available
0xF	Disabled

Appendix A Local geodetic datum tables

Table 172. Local geodetic datum for Africa

Region	Code	Code value
ADINDAN		
MeanSolution(Ethiopia-Sudan)	ADI-M	0
BurkinaFaso	ADI-E	1
Cameroon	ADI-F	2
Ethiopia	ADI-A	3
Mali	ADI-C	4
Senegal	ADI-D	5
Sudan	ADI-B	6
AFGOOYE		
Somalia	AFG	7
ARC_1950		
Mean_Solution	ARF-M	8
Botswana	ARF-A	9
Burundi	ARF-H	10
Lesotho	ARF-B	11
Malawi	ARF-C	12
Swaziland	ARF-D	13
Zaire	ARF-E	14
Zambia	ARF-F	15
Zimbabwe	ARF-G	16
ARC_1960		
Mean_Solution	ARS-M	17
Kenya	ARS-A	18
Tanzania	ARS-B	19
AYABELLE_LIGHTHOUSE		
Djibouti	PHA	20
BISSAU		
Guinea-Bissau	BID	21
CAPE		
South_Africa	CAP	22
CARTHAGE		
Tunisia	CGE	23
DABOLA		
Guinea	DAL	24
EUROPEAN_1950		
Egypt	EUR-F	73
Tunisia	EUR-T	83

Region	Code	Code value
LEIGON		
Ghana	LEH	25
LIBERIA_1964		
Liberia	LIB	26
MASSAWA		
Eritrea(Ethiopia)	MAS	27
MERCHICH		
Morocco	MER	28
MINNA		
Cameroon	MIN-A	29
Nigeria	MIN-B	30
M'PORALOKO		
Gabon	MPO	31
NORTH_SAHARA_1959		
Algeria	NSD	32
OLD_EGYPTIAN_1907		
Egypt	OEG	33
POINT_58		
Mean_Solution (BurkinaFaso-Niger)	PTB	34
POINTE_NOIRE_1948		
Congo	PTN	35
SCHWARZECK		
Namibia	SCK	36
SIERRA_LEONE_1960		
SierraLeone	SRL	37
VOIROL_1960		
Algeria	VOR	38

Table 173. Local geodetic datum for Asia

Region	Code	Code value
AIN_EL_ABD_1970		
Bahrain_Island	AIN-A	39
Saudi_Arabia	AIN-B	40
DJAKARTA(BATAVIA)		
Sumatra(Indonesia)	BAT	41
EUROPEAN_1950		
Iran	EUR-H	77
HONG_KONG_1963		
Hong_Kong	HKD	42
HU-TZU-SHAN		
Taiwan	HTN	43

Region	Code	Code value
INDIAN		
Bangladesh	IND-B	44
India-Nepal	IND-I	45
INDIAN_1954		
Thailand	INF-A	46
INDIAN_1960		
Vietnam(near_16DegNorth)	ING-A	47
ConSonIsland(Vietnam)	ING-B	48
INDIAN_1975		
Thailand	INH-A	49
Thailand	INH-A1	50
INDONESIAN_1974		
Indonesia	IDN	51
KANDAWALA		
SriLanka	KAN	52
KERTAU_1948		
WestMalaysia-Singapore	KEA	53
KOREAN_1995		
SouthKorea	KGS	54
NAHRWAN		
MasirahIsland(Oman)	NAH-A	55
UnitedArabEmirates	NAH-B	56
SaudiArabia	NAH-C	57
OMAN		
Oman	FAH	58
QATAR_NATIONAL		
Qatar	QAT	59
SOUTH_ASIA		
Singapore	SOA	60
TIMBALAI_1948		
Brunei-East_Malaysia	TIL	61
TOKYO		
MeanSolution	TOY-M	62
Japan	TOY-A	63
Okinawa	TOY-C	64
South Korea	TOY-B	65
South Korea	TOY-B1	66

Table 174. **Local geodetic datum for Australia**

Region	Code	Code value
AUSTRALIAN_1966		
Australia-Tasmania	AUA	67
AUSTRALIAN_1984		
Australia-Tasmania	AUG	68

Table 175. **Local geodetic datum for Europe**

Region	Code	Code value
CO-ORDINATE SYSTEM 1937 OF ESTONIA		
Estonia	EST	69
EUROPEAN_1950		
MeanSolution	EUR-M	70
WesternEurope	EUR-A	71
Cyprus	EUR-E	72
Egypt	EUR-F	73
England,ChannelIslands,Scotland,ShetlandIslands	EUR-G	74
England,Ireland,Scotland,ShetlandIslands	EUR-K	75
Greece	EUR-B	76
Iran	EUR-H	77
ItalySardinia	EUR-I	78
ItalySicily	EUR-J	79
Malta	EUR-L	80
Norway,Finland	EUR-C	81
Portugal,Spain	EUR-D	82
Tunisia	EUR-T	83
EUROPEAN_1979		
MeanSolution	EUS	84
HJORSEY_1955		
Iceland	HJO	85
IRELAND_1965		
Ireland	IRL	86
ORDNANCE SURVEY OF GREAT BRITAIN 1936		
MeanSolution	OGB-M	87
England	OGB-A	88
England,IsleOfMan,Wales	OGB-B	89
Scotland,ShetlandIslands	OGB-C	90
Wales	OGB-D	91
ROME_1940		
Sardinia	MOD	92
S-42(PULKOVO_1942)		
Hungary	SPK-A	93

Region	Code	Code value
Poland	SPK-B	94
Czechoslovakia	SPK-C	95
Latvia	SPK-D	96
Kazakhstan	SPK-E	97
Albania	SPK-F	98
Romania	SPK-G	99
S-JTSK		
Czechoslovakia	CCD	100

Table 176. Local geodetic datum for North America

Region	Code	Code value
CAPE_CANAVERAL		
MeanSolution(Florida,Bahamas)	CAC	101
NORTH AMERICAN 1927		
MeanSolution	NAS-C	102
WesternUnitedStates	NAS-B	103
EasternUnitedStates	NAS-A	104
Alaska(ExcludingAleutianIslands)	NAS-D	105
AleutianIslands(East180°W)	NAS-V	106
AleutianIslands(West180°W)	NAS-W	107
Bahamas(Excluding San Salvador Island)	NAS-Q	108
SanSalvadorIsland	NAS-R	109
CanadaMeanSolution(Including Newfoundland)	NAS-E	110
Alberta,BritishColumbia	NAS-F	111
EasternCanada	NAS-G	112
Manitoba,Ontario	NAS-H	113
NorthwestTerritories,Saskatchewan	NAS-I	114
Yukon	NAS-J	115
CanalZone	NAS-O	116
Caribbean	NAS-P	117
CentralMerica	NAS-N	118
Cuba	NAS-T	119
Greenland	NAS-U	120
Mexico	NAS-L	121
NORTH AMERICAN 1983		
Alaska(ExcludingAleutianIslands)	NAR-A	122
AleutianIslands	NAR-E	123
Canada	NAR-B	124
CONUS	NAR-C	125
Hawaii	NAR-H	126
Mexico,CentralAmerica	NAR-D	127

Table 177. **Local geodetic datum for South America**

Region	Code	Code value
BOGOTA OBSERVATORY		
Colombia	BOO	128
CAMPO NCHAUSPE 1969		
Argentina	CAI	129
CHUA ASTRO		
Paraguay	CHU	130
CORREGO ALEGRE		
Brazil	COA	131
PROVISIONAL SOUTH AMERICAN 1956		
MeanSolution	PRP-M	132
Bolivia	PRP-A	133
Northern Chile(near 19°S)	PRP-B	134
Southern Chile(near 43°S)	PRP-C	135
Colombia	PRP-D	136
Ecuador	PRP-E	137
Guyana	PRP-F	138
Peru	PRP-G	139
Venezuela	PRP-H	140
PROVISIONAL SOUTH CHILEAN		
Southern Chile(near 53°S)	HIT	141
SOUTH AMERICAN 1969		
MeanSolution	SAN-M	142
Argentina	SAN-A	143
Bolivia	SAN-B	144
Brazil	SAN-C	145
Chile	SAN-D	146
Colombia	SAN-E	147
Ecuador (Excluding Galapagos Islands)	SAN-F	148
Baltra,Galapagos Islands	SAN-J	149
Guyana	SAN-G	150
Paraguay	SAN-H	151
Peru	SAN-I	152
Trinidad and Tobago	SAN-K	153
Venezuela	SAN-L	154
SOUTH AMERICAN GEOCENTRIC REFERENCE SYSTEM(SIRGAS)		
South America	SIR	155
ZANDERIJ		
Suriname	ZAN	156

Table 178. **Local geodetic datum for Atlantic Ocean**

Region	Code	Code value
ANTIGUA ISLAND ASTRO 1943		
Antigua,Leeward Islands	AIA	157
ASCENSION ISLAND 1958		
Ascension Island	ASC	158
ASTRO DOS 71/4		
St.Helena Island	SHB	159
BERMUDA 1957		
Bermuda Islands	BER	160
CAPE CANAVERAL		
Mean Solution (Bahamas and Florida)	CAC	101
DECEPTION ISLAND		
Deception Islandand Antarctica	DID	161
FORT THOMAS 1955		
Nevis, St.Kitts and Leeward Islands	FOT	162
GRACIOSA BASE SW 1948		
Faial, Graciosa, Pico, SaoJorge and Terceira Islands (Azores)	GRA	163
HJORSEY 1955		
Iceland	HJO	85
ISTS 061 ASTRO 1968		
South Georgia Island	ISG	164
L.C. 5 ASTRO 1961		
Cayman Brac Island	LCF	165
MONTSERRAT ISLAND ASTRO 1958		
Montserrat and Leeward Islands	ASM	166
NAPARIMA,BWI		
Trinidad and Tobago	NAP	167
OBSERVATORIO METEOROLOGICO 1939		
Corvo and Flores Islands (Azores)	FLO	168
PICO DE LAS NIEVES		
Canary Islands	PLN	169
PORTO SANTO 1936		
Porto Santo and Madeira Islands	POS	170
PUERTO RICO		
Puerto Rico and Virgin Islands	PUR	171
QORNOQ		
South Greenland	QUO	172
SAO BRAZ		
Sao Miguel and Santa Maria Islands (Azores)	SAO	173
SAPPER HILL 1943		
East Falkland Island	SAP	174

Region	Code	Code value
SELVAGEM GRANDE 1938		
Salvage Islands	SGM	175
TRISTAN ASTRO 1968		
Tristan da Cunha	TDC	176

Table 179. Local geodetic datum for Indian Ocean

Region	Code	Code value
ANNA 1 ASTRO 1965		
Cocos Islands	ANO	177
GAN 1970		
Republic of Maldives	GAA	178
ISTS 073 ASTRO 1969		
Diego Garcia	IST	179
KERGUELEN ISLAND 1949		
Kerguelen Island	KEG	180
MAHE 1971		
Mahe Island	MIK	181
REUNION		
Mascarene Islands	REU	182

Table 180. Local geodetic datum for Pacific Ocean

Region	Code	Code value
AMERICAN SAMOA 1962		
American Samoa Islands	AMA	183
ASTRO BEACON “E” 1945		
Iwo Jima	ATF	184
ASTRO TERN ISLAND (FRIG) 1961		
Tern Island	TRN	185
ASTRONOMICAL STATION 1952		
Marcus Island	ASQ	186
BELLEVUE (IGN)		
Efate and Erromango Islands	IBE	187
CANTON ASTRO 1966		
Phoenix Islands	CAO	188
CHATHAM ISLAND ASTRO 1971		
Chatham Island (New Zealand)	CHI	189
DOS 1968		
Gizo Island (New Georgia Islands)	GIZ	190
EASTER ISLAND 1967		
Easter Island	EAS	191

Region	Code	Code value
GEODETIC DATUM 1949		
New Zealand	GEO	192
GUAM 1963		
Guam	GUA	193
GUX I ASTRO		
Guadalcanal Island	DOB	194
INDONESIAN 1974		
Indonesia	IDN	51
JOHNSTON ISLAND 1961		
Johnston Island	JOH	195
KUSAIE ASTRO 1951		
CarolineIslands, Fed.States of Micronesia	KUS	196
LUZON		
Philippines (Excluding Mindanao Island)	LUZ-A	197
Mindanao Island	LUZ-B	198
MIDWAY ASTRO 1961		
Midway Islands	MID_A	199
Midway Islands	MID_B	200
OLD_HAWAIIAN		
Mean Solution	OHA-M	201
Hawaii	OHA-A	202
Kauai	OHA-B	203
Maui	OHA-C	204
Oahu	OHA-D	205
OLD HAWAIIAN		
Mean Solution	OHI-M	206
Hawaii	OHI-A	207
Kauai	OHI-B	208
Maui	OHI-C	209
Oahu	OHI-D	210
PITCAIRN ASTRO 1967		
Pitcairn Island	PIT	211
SANTO (DOS) 1965		
Espirito Santo Island	SAE	212
VITI LEVU 1916		
VitiLevuIsland (Fiji Islands)	MVS	213
WAKE-ENIWETOK 1960		
Marshall Islands	ENW	214
WAKE ISLAND ASTRO 1952		
Wake Atoll	WAK	215

Table 181. **Non-satellite derived transformation parameter**

Region	Code	Code value
BUKIT RIMPAH		
Bangka and Belitung Islands (Indonesia)	BUR	216
CAMP AREA ASTRO		
Camp McMurdo Area, Antarctica	CAZ	217
EUROPEAN 1950		
Iraq, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria	EUR-S	218
GUNUNG SEGARA		
Kalimantam (Indonesia)	GSE	219
HERAT NORTH		
Afghanistan	HEN	220
HERMANNSKOGEL		
Slovenia, Croatia, Bosnia and Herzegovina, Serbia	HER	221
INDIAN		
Pakistan	IND_P	222
PULKOVO 1942		
Russia	PUK	223
TANANARIVE OBSERVATORY 1925		
Madagascar	TAN	224
VOIROL 1874		
Tunisia, Algeria	VOI	225
YACARE		
Uruguay	YAC	226

Table 182. **Terrestrial reference systems**

	Code	Code value
GLONASS		
PZ90.2	PZ90_2	227
PZ90.11	PZ90_11	254

Appendix B Acronyms and reference documents

Table 183. Acronyms

Keyword	Definition
ACM	Auto-correlation metric
ADC	Analog-to-digital converter
ADR	Accumulated doppler range in meters
CDB	Configuration data block
CN0	Carrier to noise density ratio [dB/Hz]
CWM	Narrow band carrier wave monitor
E2E	End to end
ECEF	Earth centered earth fixed
PSR	Pseudorange in meters
F_0	1.023000 MHz
FCCU	Fault collection and control unit
GLONASS	Global'naja navigacionnaja sputinkovaja sistema
GNSS	Global navigation satellite system
GPS	Global positioning system
HDOP	Horizontal dilution of precision
IFB	Inter-frequency bias
LS	Least squares
LSB	Least significant bit
MSB	Most significant bit
NMEA	National marine electronics association
NVM	Non-volatile memory
OBSQM	Observable quality metric
PDOP	Position dilution of precision
PPP	Precise point positioning
PPS	Pulse per second
PVT	Position, velocity, time
RFU	Reserved for further use.
SPP	Single point positioning
SQM	Signal quality metric
SV	Space vehicle
TCXO	Temperature controlled oscillator
VDOP	Vertical dilution of precision

Table 184. Reference documents

Document name	Document title
UM3397	Teseo VI and Teseo APP2–NMEA observables description
UM3407	Teseo VI and Teseo APP2–NMEA specifications and commands
UM3428	Teseo VI and Teseo APP2–Firmware configuration

Document name	Document title
UM3432	Teseo VI–Assisted GNSS interface specification
RTCM standard	Differential GNSS (global navigation satellite systems) services

Revision history

Table 185. **Document revision history**

Date	Revision	Changes
12-Dec-2024	1	Initial release.
30-Jan-2025	2	Updated Table 6, Table 14, Table 15, Table 21, Table 22, and Table 23, and Section 4.9: Data retransmission request (TXREQ). Removed from Section 4.16: Test message (TEST) the content inserted in new Section 4.17: Response message (RESP). Updated Section 4.18, Table 81 and two crossreferences in the below text, Table 89, title of Table 113, and Table 151. Removed from Table 148 the content inserted in the new Table 149, and added Table 150. Updated items in the Note.
18-Apr-2025	3	Updated *Table 75. RF status (RFS)*, *Table 78. WBJ/IFM data (reported status mask bit 2 =1)*; *Table 79. Noise floor data (reported status mask bit 3 = 1)*, *Table 89. RF status (RFS)*, and *Table 153. MTI group IDs*.
30-Apr-2025	4	Updated *Table 78. WBJ/IFM data (reported status mask bit 2 = 1)* and *Table 89. RF status (RFS)*. Minor text changes.
08-Jul-2025	5	Updated *Section 4.1: Message timing and scheduling*, *Table 7. Data fields*, *Table 14. Host integrity / extended PVT*, *Table 29. DF22P metrics mask (observable quality)*, *Table 30. DF22P metrics mask 2 (observable quality)*, *Table 32. Retransmission message ID*, *Table 38. Auxiliary message (ID 22, type FEDUMP) retransmission additional data*, *Table 66. Auxiliary IDs*, *Table 67. Auxiliary data chip ID (CHIPID)*, and *Table 85. Extended CW data (extended status mask bit 0 = 1)*. Updated title of *Section 4.36.7: Set Merkle tree root (SETMTR)*, *Table 136. Set Merkle tree root parameters (SETMTR)*, *Section 4.36.8: Clear Merkle tree root (CLRMTR)*, and *Table 137. Clear Merkle tree root parameters (CLRMTR)*. Added a sentence just after *Table 30*, added *Table 40. CUSTOTP_READ retransmission additional data* and "Customer OTP read" part at the end of *Section 4.18: Auxiliary message (AUX)*. Removed "Response message (RESP)" part in *Section 4.16: Test message (TEST)*. Minor text changes.
10-Jul-2025	6	Updated *Updated Table 62. DF51P test ID definition, Table 66. Auxiliary IDs, Table 67. Auxiliary data chip ID (CHIPID), Table 84. Extended data (reported status mask bit 7 = 1), and Table 85. Extended CW data (extended status mask bit 0 = 1)*. Minor text changes.
21-Nov-2025	7	Updated *Section 1: Overview* and *Table 5. Standard RTCM3 messages*. Updated *Section 4.7: Signal quality metrics 2 (SIGQM2)*. Updated *Table 7. Data fields* and *Section 4.5: Extended PVT (EPVT)*. Updated *Table 30. Retransmission message ID*, *Table 37. GNSS OSNMA (STNMA) (ID 19) retransmission additional data* and *Table 48. DF40P restart mask definition*. Added *Table 65. Auxiliary data CPU results (CPU)*. Updated *Table 84. Extended data (reported status mask bit 7 = 1)* and *Table 85. Extended CW data (extended status mask bit 0 = 1)*. Added *Table 82. Updated anti-spoofing data version 1 (reported status mask bit 5 = 1)* and *Table 89. Extended antenna sensing data (extended status mask bit 4 = 1)*. Updated *Table 92. GNSS RAIM parameters (STGBS)*. Added *Table 117. Message frame for rear wheels speeds (sensor type = 18)*, *Table 116. Message frame for speed data (sensor type = 14)*, *Table 129. BCNAV2 and BCNAV3 Almanac data*, *Section 4.36: Signal quality metrics 3 (SIGQM3)* and *Section 4.37: Observable quality metrics 2 (OBSQM2)*. Updated *Table 141. Proprietary RTCM3 STNMA messages*.

Date	Revision	Changes
		Removed "*Number selector (NS)*" Added *Section 4.38.6: Get public keys (GETPK)*, *Section 4.38.7: Clear public key (CLRPK)*, *Section 4.38.9: Get merkle tree roots (GETMTR)*, *Section 4.38.12: Get intermediate tree nodes (GETITN)*, *Section 4.38.16: Get DSM blocks (GETDSM)* and *Section 4.38.17: Set DSM blocks (SETDSM)*. Updated *Table 157. Proprietary RTCM3 STNMAEVT messages*, *Table 167. OSNMA authenticated minimum specific data (STAMC) (FW config P22L8F1 = 0 for height on 20 bits)*, *Table 168. Init position (INITPOS)*. Added *Section 4.43: Time and global information (TG)*. Updated *Table 171. MTI group IDs*.
01-Dec-2025	8	Updated Table 19. DF56P compact metrics mask (signal quality) and Table 20. DF56P compact metrics mask 2 (signal quality). Updated Table 133. Signal quality metrics 3 (SIGQM3) with metric mask DF22P bit 31 = 0 and Table 134. Signal quality metrics 3 (SIGQM3) with metrics mask DF22P bit 31 = 1. Updated Table 141. Proprietary RTCM3 STNMA messages, Table 147. Get public keys (GETPK), and Table 163. NMA status event (NMA_STATUS). Updated Table 166. OSNMA authenticated minimum specific data (STAMC) and removed *Table 167. OSNMA authenticated minimum specific data (STAMC) (FW config P22L8F1 = 0 for height on 20 bits)*. Minor text changes.

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