3GPP TSG RAN WG2 Meeting #116-Bis-e R2-22xxxxx

Electronic meeting, 17 – 25 January 2022

**Agenda item:** 8.11.5

**Source:** Swift Navigation

**Title:** Report of [AT116bis-e][611][POS] GNSS integrity (Swift)

**Document for:** Discussion and decision

# Introduction

This is the template and summary for following email discussion:

 **[AT116bis-e][611][POS] GNSS integrity (Swift)**

Scope: Start discussion of the proposals from R2-2200012 to determine agreeability and resulting spec impact.

Intended outcome: Report to Wednesday online session (including revision of R2-2200012 if needed)

      Deadline:  **Tuesday 2022-01-18 2200 UTC**

The draft CRs in [R2-2200013](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_116bis-e/Inbox/R2-2200013.zip) and [R2-2200014](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_116bis-e/Inbox/R2-2200014.zip) contain the corresponding text proposals.

# Annex: Companies’ point of contact

|  |  |  |
| --- | --- | --- |
| **Company** | **Point of contact** | **Email address** |
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# Stage 2 Proposals

A set of questions are provided below to discuss the proposals from **R2-2200012 Report of [Post116-e][602][POS] Stage 2 baseline for integrity assistance data (Swift)**. The text proposed in the corresponding TPs for TS 36.305 (R2-2200013) and TS 38.305 (R2-2200014) is identical and has also been included in Appendix A for reference.

Proposal 1 (R2-2200012): Agree to add the Integrity Principle of Operation (8.1.1.1) text from R2-2200013 and R2-2200014 into TS 36.305 and TS 38.305 respectively.

**Question 1: Do you agree to add the description for the Integrity Principle of Operation (8.1.1.1),** **as proposed in R2-2200013 and R2-2200014?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Intel | Agree |
| Huawei, HiSilicon | Agree, but it might be better not to put this section under the section “general”. Better location of the section can be 8.1.x.  Also, please see the comments inlined in the text proposal |
| Swift Navigation | Agree. Regarding Huawei’s comments, we don’t mind if it is located under Section 8.1.1.1 or 8.1.x. Presently it is under 8.1.1.1 because in the prior Stage 2 CRs (R2-2111447/R2-2111448) the general integrity functionality was introduced under 8.1.1 already, so we added the Principle of Operation as a subset, as per the discussion in R2-2200012. Another option would be putting it under 8.1.1a.  We have also responded to the inline comments. |
| ZTE | Agree with the content, and we wonder if the integrity principle of operation is universal for all positioning methods, that is, whether this can be applied for RAT-dependent methods in Rel-18. If yes, it might be better to put this section under section 5, 6, or 7. |
| OPPO | Agree |
| InterDigital | Agree |
| CATT | Agree. Integrity in Rel-17 only focuses on GNSS so we prefer to keep the principle of operation still in 8.1.1 as a subset which is proposed by Swift. |
|  |  |

Proposal 2: Agree to add the baseline integrity descriptions from R2-2200013 and R2-2200014 to the existing Stage 2 descriptions for the SSR Code Bias (8.1.2.1.23), SSR Phase Bias (8.1.2.1.24), SSR STEC Corrections (8.1.2.1.25) and SSR Gridded Corrections (8.1.2.1.26). Final wording is subject to the outcomes of Stage 3 and depends on which integrity IEs and associated fields are included in LPP.

NOTE: A Stage 3 proposal which follows the structure above has also been submitted in [R2-2201214](https://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_116bis-e/Docs/R2-2201214.zip).

**Question 2: Do you agree to add the descriptions for the SSR Code Bias (8.1.2.1.23), SSR Phase Bias (8.1.2.1.24), SSR STEC Corrections (8.1.2.1.25) and SSR Gridded Corrections (8.1.2.1.26), as proposed in R2-2200013 and R2-2200014?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Intel | Agree |
| Huawei, HiSilicon | Agree |
| Swift Navigation | Agree |
| ZTE | Agree |
| OPPO | Agree |
| InterDigital | Agree |
| CATT | Agree |
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Proposal 3: Agree to add the Integrity Service Parameters (8.1.2.1.29) and Integrity Alerts (8.1.2.1.30) descriptions from R2-2200013 and R2-2200014 into TS 36.305 and TS 38.305 respectively.

**Question 3: Do you agree to add the descriptions for the Integrity Service Parameters (8.1.2.1.29) and Integrity Alerts (8.1.2.1.30) descriptions, as proposed in R2-2200013 and R2-2200014?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Intel | Agree |
| Huawei, HiSilicon | Agree |
| Swift Navigation | Agree |
| ZTE | Agree |
| Agree |  |
| InterDigital | Agree |
| CATT | Agree |
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Proposal 4: RAN2 to discuss whether the Integrity Orbit Clock Error Bounds (as per R2-2200013 and R2-2200014) should be included as a new IE or incorporated into the existing SSR Orbit and SSR Clock correction IEs in Stage 2. This discussion is also subject to the Stage 3 outcomes regarding which IEs and associated fields to define for integrity.

Four options corresponding to this proposal were presented in [R2-2201214](https://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_116bis-e/Docs/R2-2201214.zip) and the relevant text is copied below:

* In the regular SSR assistance data for GNSS positioning, the orbit and clock corrections are sent individually using the GNSS-SSR-OrbitCorrections and GNSS-SSR-ClockCorrections IEs. In practice, Orbit and Clock errors are highly correlated due to the nature of GNSS observations. For integrity, the system must be capable of handling very low levels of integrity risk (10-6, 10-7 etc), but the system’s ability decorrelate the orbit and clock errors at such low levels of risk is challenging or impossible for reaching the target Protection Levels. To overcome this limitation, the clock can also be treated together with the three components of the orbit (represented as along track, cross track and radial). Therefore, instead of using a single pair of mean and sigma for each orbit and clock bound, for the combined orbit/clock bound, the mean can be represented as a 4-component vector and a 4x4 covariance matrix (see Appendix B). The remaining question from the email discussion is where to group the associated integrity bounds. Several options were noted in [9] which are now further described in light of the background context above:

1. Group with the SSR Clock IE (given the clock is typically updated most frequently)
   * **Pros:** no new IE required in LPP.
   * **Cons:** more bandwidth required given the bound is now updated at the same rate as the clock; can’t reissue a new bound on an orbit update without also issuing a new clock update.
2. Duplicate within the SSR Orbit and Clock IEs
   * **Pros:** the Orbit or Clock IE can both be used to send the orbit/clock integrity information.
   * **Cons:** more bandwidth needed.
3. Add orbit and clock integrity bounds (mean, sigma) to the Orbit and Clock IEs (but without the full covariance)
   * **Pros:** more efficient messages by dividing up the integrity content; no new IE required.
   * **Cons:** not sending the full covariance can lead to larger bounds and therefore larger Protection Levels.
4. Define a separate message as a new IE
   * **Pros:** orbit/clock integrity information is sent separately (i.e. not dependent on the Orbit or Clock IE) allowing the implementation full flexibility on when to reissue new orbit/clock bounds; orbit/clock are treated together to enable tighter bounding.
   * **Cons:** a new is IE required.

**Question 4: Which option (a, b, c, d) should be used to represent the integrity bounds relating to the SSR orbit and clock corrections? Please explain your reasoning?**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **(a)** | **(b)** | **(c)** | **(d)** | **Comments** |
| Intel |  |  |  | Yes | Tend to agree d is more efficient way, and the cons is acceptable. |
| Huawei, HiSilicon |  |  |  | Yes | Signaling design should take into account the correlation between orbit and clock error. |
| Swift Navigation |  |  |  | Yes | Agree with the reasoning provided above, (d) is most efficient and enables the tightest bounds. |
| ZTE |  |  |  | Yes | D seems more clear |
| OPPO |  |  |  | Yes | Both of higher flexibility and more accurate Protection Level could be achieved. |
| InterDigital |  |  |  | Yes | We agree with moderator’s reasoning that having a new IE is more flexible |
| CATT |  |  |  | Yes | D is the most reasonable as the rapporteur summarized, especially the full flexibility on when to reissue new orbit/clock bounds; orbit/clock are treated together to enable tighter bounding. |

Proposal 5: RAN2 to discuss whether the Integrity Residual Risk Parameters (as per R2-2200013 and R2-2200014) should be included as a new IE or decomposed for inclusion into the existing Ionospheric (SSR-STEC-Corrections) and Tropospheric (SSR-GriddedCorrection) descriptions in Stage 2. This discussion is also subject to the Stage 3 outcomes regarding which IEs and associated fields to define for integrity.

Two options were discussed in [R2-2201214](https://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_116bis-e/Docs/R2-2201214.zip) to address this proposal, as shown in the extracted text below:

* We note that this discussion also extends to the satellite and constellation residual risk parameters. Based on the Stage 2 discussion there are two main options on where to define these residual risk parameters:

1. Incorporate each parameter into their corresponding GNSS IEs
   * **Pros:** less complexity in trying to match the IODs (they are implicitly aligned); can reuse existing IEs (note that the Satellite and Constellation residual risks could fit within the proposed *GNSS-Integrity-OrbitClockErrorBounds*, see Section 2.2.1 above).
   * **Cons:** more bandwidth is consumed by reissuing the residual risk (even if it is static) with each correction.
2. Create a new IE which groups the residual risk parameters into a standalone IE
   * **Pros:** less bandwidth (lower update rate); more flexibility in the implementation for when to reissue the residual risks.
   * **Cons:** another IE is required; cross-matching with other GNSS IEs can be more complicated.

**Question 5: Which option do you choose (a, b) on where to place the residual risk parameters for the corresponding GNSS / SSR IEs? Please explain your reasoning.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **(a)** | **(b)** | **Comments** |
| Intel | Yes |  | Would like to avoid additional complex although option b is more flexible. |
| Huawei, HiSilicon | Yes |  |  |
| Swift Navigation | Yes |  | Agree with the reasoning provided above. |
| ZTE | Yes |  |  |
| OPPO | Yes |  |  |
| InterDigital | Yes |  | Agree with moderator’s analysis for incorporating into GNSS IEs |
| CATT | Yes |  |  |
|  |  |  |  |

Proposal 6: Agree to add Section 8.1.2.1b-1 and Table 8.1.2.1b-1 from R2-2200013 and R2-2200014 into TS 36.305 and TS 38.305 respectively. The field names in Table 8.1.2.1b-1 are subject to the outcomes of Stage 3 regarding which integrity IEs and associated fields to include in LPP.

**Question 6: Do you agree to add Section 8.1.2.1b-1 and Table 8.1.2.1b-1, as per R2-2200013 and R2-2200014?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Intel | Yes |
| Huawei, HiSilicon | OK with the format. |
| Swift Navigation | Yes |
| ZTE | Yes |
| OPPO | Yes |
| InterDigital | Yes |
| CATT | Yes |

**Question 7: Any other questions or comments on the draft CRs (R2-2200013 and R2-2200014)?**

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| --- | --- |
| **Company** | **Comments** |
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# Summary report and proposals

To be updated.

# Appendix A

The following text has been extracted from [R2-2200014](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_116bis-e/Inbox/R2-2200014.zip) (TS 38.305) and is the same text that is proposed in [R2-2200013](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_116bis-e/Inbox/R2-2200013.zip) for TS 36.305. The text is provided as a reference to assist in answering the questions above.

<<<<<<<<<<<<<<<<<<<< First change begins >>>>>>>>>>>>>>>>>>>>

8 Positioning methods and Supporting Procedures

8.1 GNSS positioning methods

8.1.1 General

A navigation satellite system provides autonomous geo-spatial positioning with either global or regional coverage. Augmentation systems, such as SBAS, are navigation satellite systems that provide regional coverage to augment the navigation systems with global coverage.

By definition, GNSS refers to satellite constellations that achieve global coverage, however, in 3GPP specifications the term GNSS is used to encompass global, regional, and augmentation satellite systems. The following GNSSs are supported in this version of the specification:

- GPS and its modernization [5], [6], [7]; (global coverage)

- Galileo [8]; (global coverage)

- GLONASS [9]; (global coverage)

- Satellite Based Augmentation Systems (SBAS), including WAAS, EGNOS, MSAS, and GAGAN [11]; (regional coverage)

- Quasi-Zenith Satellite System (QZSS) [10]; (regional coverage)

- BeiDou Navigation Satellite System (BDS) [20] [34]. (global coverage)

Each global GNSS can be used individually or in combination with others, including regional navigation systems and augmentation systems. When used in combination, the effective number of navigation satellite signals would be increased:

- extra satellites can improve availability (of satellites at a particular location) and results in an improved ability to work in areas where satellite signals can be obscured, such as in urban canyons;

- extra satellites and signals can improve reliability, i.e., with extra measurements the data redundancy is increased, which helps identify any measurement outlier problems;

- extra satellites and signals can improve accuracy due to improved measurement geometry and improved ranging signals from modernized satellites.

When GNSS is designed to inter-work with the NG-RAN, the network assists the UE GNSS receiver to improve the performance in several respects. These performance improvements will:

- reduce the UE GNSS start-up and acquisition times; the search window can be limited and the measurements speed up significantly;

- increase the UE GNSS sensitivity; positioning assistance messages are obtained via NG-RAN so the UE GNSS receiver can operate also in low SNR situations when it is unable to demodulate GNSS satellite signals;

- allow the UE to consume less handset power than with stand-alone GNSS; this is due to rapid start-up times as the GNSS receiver can be in idle mode when it is not needed;

- allow the UE to compute its position with a better accuracy; RTK corrections (for N-RTK) and GNSS physical models (for SSR/PPP) are obtained via NG-RAN so the UE can use these assistance data, together with its own measurements, i.e., code and carrier phase measurements, to enable computation of a position with a high accuracy.

The network-assisted GNSS methods rely on signalling between UE GNSS receivers (possibly with reduced complexity) and a continuously operating GNSS reference receiver network, which has clear sky visibility of the same GNSS constellation as the assisted UEs. Two assisted modes are supported:

*- UE-Assisted*: The UE performs GNSS measurements (pseudo-ranges, pseudo Doppler, carrier phase ranges, etc.) and sends these measurements to the LMF where the position calculation takes place, possibly using additional measurements from other (non GNSS) sources;

*- UE-Based*: The UE performs GNSS measurements and calculates its own location, possibly using additional measurements from other (non GNSS) sources and assistance data from the LMF.

The assistance data content may vary depending on whether the UE operates in UE-Assisted or UE-Based mode.

The assistance data signalled to the UE can be broadly classified into:

- *data assisting the measurements*: e.g. reference time, visible satellite list, satellite signal Doppler, code phase, Doppler and code phase search windows;

- *data providing means for position calculation*: e.g. reference time, reference position, satellite ephemeris, clock corrections, code and carrier phase measurements from a GNSS reference receiver or network of receivers;

- *data increasing the position accuracy*: e.g. satellite code biases, satellite orbit corrections, satellite clock corrections, atmospheric models, RTK residuals, gradients.

A UE with GNSS measurement capability may also operate in an autonomous (standalone) mode. In autonomous mode the UE determines its position based on signals received from GNSS without assistance from the network.

8.1.1.1 Integrity Principle of Operation

For integrity operation, the network will ensure that:

**(Equation 8.1.1.1-1)**

for all values of IRallocation in the range irMinimum <= IRallocation <= irMaximum

for all the errors in Table 8.1.2.1b-1, which have corresponding integrity assistance data available and where the corresponding DNU flag is set to false.

The integrity risk probability is decomposed into a constant Residual Risk component provided in the assistance data as well as a variable IRallocation component that corresponds to the contribution from the Bound according to the Bound formula in Equation 8.1.1.1-2. IRallocation may be chosen freely by the client based on the desired Bound, therefore the network can ensure that Equation 8.1.1.1-1 holds for all possible choices of IRallocation. The Residual Risk and IRallocation components may be mapped to fault and fault-free cases respectively, but the implementation is free to choose any other decomposition of the integrity risk probability into these two components.

Where:

**Error:** Error is the difference between the true value of a GNSS error, and its value as estimated and provided in the corresponding assistance data as per Table 8.1.2.1b-1

**Bound:** Integrity Bounds provide the statistical distribution of the residual errors associated with the GNSS positioning corrections (e.g. RTK, SSR etc). Integrity bounds are used to statistically bound the residual errors after the positioning corrections have been applied. The bound is computed according to the Bound formula defined in Equation 8.1.1.1-2. The bound formula describes a bounding model including a mean and standard deviation (e.g. paired over-bounding Gaussian). The bound may be scaled by multiplying the standard deviation by a K factor corresponding to an IRallocation, for any desired IRallocation within the permitted range.

Bound for a particular error is computed according to the following formula:

*Bound = mean + K \* stdDev* **(Equation 8.1.1.1-2)**

*K = normInv(IRallocation / 2)*

*irMinimum <= IRallocation <= irMaximum*

Where:

*mean*: mean value for this specific error, as per Table 8.1.2.1b-1

*stdDev*: standard deviation for this specific error, as per Table 8.1.2.1b-1

**DNU:** The DNU flag corresponding to a particular error as per Table 8.1.2.1b-1. Where multiple DNU flags are specified, the DNU condition in Equation 8.1.1.1-1 is present when any of the flags are true (logical OR of the flags).

**Residual Risk:** The residual risk is the component of the integrity risk provided in the assistance data as per Table 8.1.2.1b-1. This may correspond to the fault case risk but the implementation is permitted to allocate this component in any way that satisfies Equation 8.1.1.1-1.

**irMinimum, irMaximum:** Minimum and maximum allowable values of IRallocation that may be chosen by the client. Provided as service parameters from the Network according to Integrity Service Parameters.

**Correlation Times:** The minimum time interval beyond which two sets of GNSS assistance data parameters for a given error can be considered to be independent from one another.

NOTE: Equation 8.1.1.1-1 holds for all assistance data that has been issued that is still within its validity period. If this condition cannot be met then a DNU flag must be set.

NOTE: Equation 8.1.1.1-1 holds only at the epoch time of the DNU flag. The condition is not required to be met at any other times or when no DNU flags are available, i.e. DNU flags are affirmative and non-presence of the DNU IEs should not be interpreted as a usable condition. It is up to the implementation how to handle epochs for which integrity results are desired but there is no DNU flag available, e.g. the Time To Alert (TTA) may be set such that there is a “grace period” to receive the next set of DNU flags.

8.1.2 Information to be transferred between NG-RAN/5GC Elements

This clause defines the information that may be transferred between LMF and UE.

8.1.2.1 Information that may be transferred from the LMF to UE

Table 8.1.2.1-1 lists assistance data for both UE-assisted and UE-based modes that may be sent from the LMF to the UE.

NOTE: The provision of these assistance data elements and the usage of these elements by the UE depend on the NG-RAN/5GC and UE capabilities, respectively.

**Table 8.1.2.1-1: Information that may be transferred from the LMF to UE**

|  |
| --- |
| **Assistance Data** |
| Reference Time |
| Reference Location |
| Ionospheric Models |
| Earth Orientation Parameters |
| GNSS-GNSS Time Offsets |
| Differential GNSS Corrections |
| Ephemeris and Clock Models |
| Real-Time Integrity |
| Data Bit Assistance |
| Acquisition Assistance |
| Almanac |
| UTC Models |
| RTK Reference Station Information |
| RTK Auxiliary Station Data |
| RTK Observations |
| RTK Common Observation Information |
| GLONASS RTK Bias Information |
| RTK MAC Correction Differences |
| RTK Residuals |
| RTK FKP Gradients |
| SSR Orbit Corrections |
| SSR Clock Corrections |
| SSR Code Bias |
| SSR Phase Bias |
| SSR STEC Corrections |
| SSR Gridded Correction |
| SSR URA |
| SSR Correction Points |
| Integrity Service Parameters |
| Integrity Alerts |
| Integrity Residual Risk Parameters |
| Integrity Orbit Clock Error Bounds |

8.1.2.1.1 Reference Time

Reference Time assistance provides the GNSS receiver with coarse or fine GNSS time information. The specific GNSS system times (e.g., GPS, Galileo, GLONASS, BDS system time) shall be indicated with a GNSS ID.

In case of coarse time assistance only, the Reference Time provides an estimate of the current GNSS system time (where the specific GNSS is indicated by a GNSS ID). The LMF should achieve an accuracy of ±3 seconds for this time including allowing for the transmission delay between LMF and UE.

In case of fine time assistance, the Reference Time provides the relation between GNSS system time (where the specific GNSS is indicated by a GNSS ID) and NG-RAN air-interface timing.

8.1.2.1.2 Reference Location

Reference Location assistance provides the GNSS receiver with an a priori estimate of its location (e.g., obtained via Cell-ID, OTDOA positioning, etc.) together with its uncertainty.

The geodetic reference frame shall be WGS-84, as specified in TS 23.032 [4].

8.1.2.1.3 Ionospheric Models

Ionospheric Model assistance provides the GNSS receiver with parameters to model the propagation delay of the GNSS signals through the ionosphere. Ionospheric Model parameters as specified by GPS [5], Galileo [8], QZSS [10], and BDS [20] [34] may be provided.

8.1.2.1.4 Earth Orientation Parameters

Earth Orientation Parameters (EOP) assistance provides the GNSS receiver with parameters needed to construct the ECEF-to-ECI coordinate transformation as specified by GPS [5].

8.1.2.1.5 GNSS-GNSS Time Offsets

GNSS-GNSS Time Offsets assistance provides the GNSS receiver with parameters to correlate GNSS time (where the specific GNSS is indicated by a GNSS-1 ID) of one GNSS with other GNSS time (where the specific GNSS is indicated by a GNSS-2 ID). GNSS-GNSS Time Offsets parameters as specified by GPS [5], Galileo [8], GLONASS [9], QZSS [10], and BDS [20] [34] may be provided.

8.1.2.1.6 Differential GNSS Corrections

Differential GNSS Corrections assistance provides the GNSS receiver with pseudo-range and pseudo-range-rate corrections to reduce biases in GNSS receiver measurements as specified in [12]. The specific GNSS for which the corrections are valid is indicated by a GNSS-ID.

8.1.2.1.7 Ephemeris and Clock Models

Ephemeris and Clock Models assistance provides the GNSS receiver with parameters to calculate the GNSS satellite position and clock offsets. The various GNSSs use different model parameters and formats, and all parameter formats as defined by the individual GNSSs are supported by the signalling.

8.1.2.1.8 Real-Time Integrity

Real-Time Integrity assistance provides the GNSS receiver with information about the health status of a GNSS constellation (where the specific GNSS is indicated by a GNSS ID).

8.1.2.1.9 Data Bit Assistance

Data Bit Assistance provides the GNSS receiver with information about data bits or symbols transmitted by a GNSS satellite at a certain time (where the specific GNSS is indicated by a GNSS ID). This information may be used by the UE for sensitivity assistance (data wipe-off) and time recovery.

8.1.2.1.10 Acquisition Assistance

Acquisition Assistance provides the GNSS receiver with information about visible satellites, reference time, expected code-phase, expected Doppler, search windows (i.e., code and Doppler uncertainty) and other information of the GNSS signals (where the specific GNSS is indicated by a GNSS ID) to enable a fast acquisition of the GNSS signals.

8.1.2.1.11 Almanac

Almanac assistance provides the GNSS receiver with parameters to calculate the coarse (long-term) GNSS satellite position and clock offsets. The various GNSSs use different model parameters and formats, and all parameter formats as defined by the individual GNSSs are supported by the signalling.

8.1.2.1.12 UTC Models

UTC Models assistance provides the GNSS receiver with parameters needed to relate GNSS system time (where the specific GNSS is indicated by a GNSS ID) to Universal Coordinated Time. The various GNSSs use different model parameters and formats, and all parameter formats as defined by the individual GNSSs are supported by the signalling.

8.1.2.1.13 RTK Reference Station Information

RTK Reference Station Information provides the GNSS receiver with the Earth-Centered, Earth-Fixed (ECEF) coordinates of the Reference Station's installed antenna's ARP, and the height of the ARP above the survey monument. Additionally, this assistance data provides information about the antenna type installed at the reference site.

NOTE: With the MAC N-RTK technique this assistance data is used to provide information regarding the Master Reference Station (see clause 8.1.2.1a).

8.1.2.1.14 RTK Auxiliary Station Data

RTK Auxiliary Station Data provides the GNSS receiver with the location for all Auxiliary Reference Stations (see clause 8.1.2.1a) within the assistance data. These values are expressed as relative geodetic coordinates (latitude, longitude, and height) with respect to a Master Reference Station (see clause 8.1.2.1a) and based on the GRS80 ellipsoid. This type of assistance data is relevant only with the MAC N-RTK technique [31].

8.1.2.1.15 RTK Observations

RTK Observations provides the GNSS receiver with all primary observables (pseudo-range, phase-range, phase-range rate (Doppler), and carrier-to-noise ratio) generated at the Reference Station for each GNSS signal. The signal generation from the reference station is in compliance with [31]: as an example, the phase measurements of different signals in the same band must be phased aligned. More examples can be found in [31].

The pseudo-range is the distance between the satellite and GNSS receiver antennas, expressed in metres, equivalent to the difference of the time of reception (expressed in the time frame of the GNSS receiver) and the time of transmission (expressed in the time frame of the satellite) of a distinct satellite signal.

The phase-range measurement is a measurement of the range between a satellite and receiver expressed in units of cycles of the carrier frequency. This measurement is more precise than the pseudo-range (of the order of millimetres), but it is ambiguous by an unknown integer number of wavelengths.

The phase-range rate is the rate at which the phase-range between a satellite and a GNSS receiver changes over a particular period of time.

The carrier-to-noise ratio is the ratio of the received modulated carrier signal power to the noise power after the GNSS receiver filters.

NOTE: With the MAC N-RTK technique this assistance data is used to provide raw observables recorded at the Master Reference Station (see clause 8.1.2.1a).

8.1.2.1.16 RTK Common Observation Information

RTK Common Observation Information provides the GNSS receiver with common information applicable to any GNSS, e.g. clock steering indicator. This assistance data is always used together GNSS RTK Observations (see clause 8.1.2.1.15).

8.1.2.1.17 GLONASS RTK Bias Information

RTK Bias Information provides the GNSS receiver with information which is intended to compensate for the first-order inter-frequency phase-range biases introduced by the reference receiver code-phase biases. This information is applicable only for GLONASS FDMA signals. In the case that the MAC Network RTK method is used, GLONASS RTK Bias Information defines the code-phase biases related to the Master Reference Station [31].

8.1.2.1.18 RTK MAC Correction Differences

RTK MAC Correction Differences provides the GNSS receiver with information about ionospheric (dispersive) and geometric (non-dispersive) corrections generated between a Master Reference Station and its Auxiliary Reference Stations [31].

8.1.2.1.19 RTK Residuals

RTK Residuals provides the GNSS receiver with network error models generated for the interpolated corrections disseminated in Network RTK techniques. With sufficient redundancy in the RTK network, the location server process can provide an estimate for residual interpolation errors. Such quality estimates may be used by the target UE to optimize the performance of RTK solutions. The values may be considered by the target UE as a priori estimates only, with sufficient tracking data available the target UE might be able to judge residual geometric and ionospheric errors itself. According to [31], RTK Residual error information should be transmitted every 10-60 seconds.

8.1.2.1.20 RTK FKP Gradients

RTK FKP Gradients provides the GNSS receiver with horizontal gradients for the geometric (troposphere and satellite orbits) and ionospheric signal components in the observation space. According to [31], RTK FKP gradient information should be typically transmitted every 10-60 seconds.

8.1.2.1.21 SSR Orbit Corrections

SSR Orbit Corrections provides the GNSS receiver with parameters for orbit corrections in radial, along-track and cross-track components. These orbit corrections are used to compute a satellite position correction, to be combined with satellite position ­calculated from broadcast ephemeris (see clause 8.1.2.1.7).

8.1.2.1.22 SSR Clock Corrections

SSR Clock Corrections provides the GNSS receiver with parameters to compute the GNSS satellite clock correction applied to the broadcast satellite clock (see clause 8.1.2.1.7). A polynomial of order 2 describes the clock differences for a certain time period: clock offset, drift, and drift rate.

8.1.2.1.23 SSR Code Bias

SSR Code Bias provides the GNSS receiver with the Code Biases that must be added to the pseudo range measurements of the corresponding code signal to get corrected pseudo ranges. SSR Code Bias contains absolute values, but also enables the alternative use of Differential Code Biases by setting one of the biases to zero. A UE can consistently use signals for which a code bias is transmitted. It is not reliable for a UE to use a signal without retrieving a corresponding code bias from the assistance data message. For integrity purposes, SSR Code Bias also provides the mean and standard deviation that bounds the residual Code Bias Error and its associated error rate.

8.1.2.1.24 SSR Phase Bias

SSR Phase Bias provides the GNSS receiver with the GNSS signal phase bias that are added to the carrier phase measurements of the corresponding signal to get corrected phase ranges. An indicator used to count events when phase bias is discontinuous is provided. An optional indicator is also provided to indicate whether fixed, widelane fixed or float PPP-RTK positioning modes are supported on a per signal basis.

NOTE 1: On the UE side, phase bias corrections of appropriate type are needed to restore the integer nature of the phase ambiguities in PPP-RTK. Their absence will affect the quality of the positioning solution and prevent a fast convergence time.

NOTE 2: PPP-RTK Fixed position mode corresponds to the UE fixing the carrier phase ambiguity to an integer value. The PPP-RTK Widelane Fixed positioning mode corresponds to forming the widelane combination of carrier phase measurements and fixing the resulting ambiguity as an integer value. In PPP-RTK Float positioning mode the carrier phase ambiguity is not treated as an integer value.

For integrity purposes, SSR Phase Bias also provides the mean and standard deviation that bounds the residual Phase Bias Error and its associated error rate.

8.1.2.1.25 SSR STEC Corrections

SSR STEC Corrections provides the GNSS receiver with the parameters to compute the ionosphere slant delay correction based on a variable order polynomial on a per satellite basis and applied to the code and phase measurements. For integrity purposes, SSR STEC Corrections also provides the mean and standard deviation that bounds the residual Ionospheric Error and its associated error rate.

8.1.2.1.26 SSR Gridded Correction

SSR Gridded Corrections provides the GNSS receiver with STEC residuals and Troposphere delays at a series of correction points and expressed as hydrostatic and wet vertical delays.

NOTE: The final ionosphere slant delay (STEC) consists of the polynomial part provided in SSR STEC Correction and the residual part provided in SSR Gridded Corrections.

For integrity purposes, SSR Gridded Corrections also provides the mean and standard deviation that bounds the residual Tropospheric Error and associated its error rate in the Vertical Hydro Static Delay and Vertical Wet Delay components.8.1.2.1.27 SSR URA

SSR URA provides the receiver with information about the estimated accuracy of the corrections for each satellite.

8.1.2.1.28 SSR Correction Points

The SSR Correction Points provides a list of correction point coordinates or an array of correction points ("grid") for which the SSR Gridded Corrections are valid.

8.1.2.1.29 Integrity Service Parameters

Integrity Service Parameters provide the range of Integrity Risk (IR) for which the associated GNSS integrity assistance data is considered to be valid. The range shall not change during a session.

8.1.2.1.30 Integrity Alerts

Integrity Service Alerts provide information on whether the service can be used for integrity. A Do Not Use (DNU) flag indicates that the corresponding assistance data is not suitable for the purpose of computing integrity. If no DNU flag is issued, then the corresponding assistance data may be used for the purpose of computing integrity. The DNU flags are defined to be applicable to the specified epoch time only.

8.1.2.1.31 Integrity Residual Risk Parameters

Integrity Residual Risk Parameters are used to provide the residual risk parameters related to the satellite, constellation, ionosphere and troposphere residual risk probabilities and their correlation times.

8.1.2.1.32 Integrity Orbit Clock Error Bounds

Integrity Orbit Clock Error Bounds is used to provide integrity bounding parameters relating to the orbit, orbit rate, clock and clock rate residual errors after application of the SSR corrections. The correlation times for the orbit range error, orbit range rate error, clock range and clock range rate error are also provided.

8.1.2.1a Recommendations for grouping of assistance data to support different RTK service levels

This clause provides recommendations for the different high-accuracy GNSS service levels: RTK, N-RTK, PPP and PPP-RTK.

The high-accuracy GNSS methods can be classified as:

- *Single base RTK service*: RTK is a technique that uses carrier-based ranging measurements i.e., phase-range to improve the positioning accuracy in a differential approach. The basic concept is to reduce and remove errors common to a Reference Station, with known position, and UE pair. When only pseudo ranges (code-based measurements) are used to compute the UE location, this method is known as DGNSS (Differential GNSS).

**Table 8.1.2.1a-1: Single base RTK service: Specific information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| RTK Reference Station Information |
| RTK Observations |
| RTK Common Observation Information |
| GLONASS RTK Bias Information (if GLONASS data is transmitted) |
| Ephemeris and Clock (if UE did not acquire the navigation message) |

- *Non-Physical Reference Station Network RTK service*: In this approach the target UE receives synthetic observations from a fictitious Reference Station. The Network RTK software at the location server is performing the error estimation and creates a virtual Reference Station close to the initial location of the target device (provided a priori to the location server). The target UE interprets and uses the data just as if it had come from a single, real Reference Station. Additionally, the target UE can also receive network information such as RTK Network Residuals (see clause 8.1.2.1.19) or even FKP gradients (see clause 8.1.2.1.20).

**Table 8.1.2.1a-2: Non-Physical Reference Station Network RTK service: Specific information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| RTK Reference Station Information |
| RTK Observations |
| RTK Common Observation Information |
| GLONASS RTK Bias Information (if GLONASS data is transmitted) |
| RTK Residuals |
| RTK FKP Gradients |
| Ephemeris and Clock (if UE did not acquire the navigation message) |

- *MAC Network RTK service*: In MAC network RTK, a group of Reference Stations are used and one of them is chosen as a Master station. The other stations are then called Auxiliary stations. In this service, the location server sends full raw observations and coordinate information for a single Reference Station, the Master Station. For all auxiliary stations in the network (or a suitable subset of stations) the information is provided to the UE in a highly compact form: their reduced ambiguity-levelled observations, coordinate differences (to the Master Station observations and coordinates), and network residuals. Two Reference Stations are said to be on a common ambiguity level if the integer ambiguities for each phase range (satellite-receiver pair) have been removed (or adjusted) so that the integer ambiguities cancel when double-differences (involving two receivers and two satellites) are formed during processing. The maintenance of a common ambiguity level at a specific set of stations rather than across the whole GNSS network will lead to a grouping in network clusters or subnetworks of all ambiguity-levelled Reference Stations. If one network has only one subnetwork, this indicates that an ambiguity level throughout the whole network is established. When subnetworks are predefined, the assistance data can be broadcast to all UEs located in the assigned sub-network. More details on the usage of subnetworks can be found in [31].

**Table 8.1.2.1a-3: MAC Network RTK service: Specific Information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| RTK Reference Station Information |
| RTK Auxiliary Station Data |
| RTK Observations |
| RTK Common Observation Information |
| GLONASS RTK Bias Information (if GLONASS data is transmitted) |
| RTK MAC Correction Differences |
| RTK Residuals |
| Ephemeris and Clock (if UE did not acquire the navigation message) |

- *FKP Network RTK service*: With the concept of FKP, horizontal gradients of distance-dependent errors like ionosphere, troposphere and orbits are derived from a network of GNSS Reference Stations and transmitted to a target device together with raw or correction data of a corresponding Reference Station (physical or non physical). The target UE may use the gradients to compute the effect of the distance-dependent errors for its own position.

**Table 8.1.2.1a-4: FKP Network RTK service: Information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| RTK Reference Station Information |
| RTK Observations |
| RTK Common Observation Information |
| GLONASS RTK Bias Information (if GLONASS data is transmitted) |
| RTK Residuals |
| RTK FKP Gradients |
| Ephemeris and Clock (if UE did not acquire the navigation message) |

- *PPP service*: This concept uses precise satellite orbit and clock parameters derived from global networks of Reference Stations as well as atmospheric models to perform single station positioning [31]. Compared to RTK and Network RTK, PPP is not a differential technique as there is no baseline limitation. When the orbits and clocks assistance data elements are provided in real-time, with no latency, the method is called Real-Time PPP.

**Table 8.1.2.1a-5: SSR PPP service: Information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| SSR Orbit Corrections |
| SSR Clock corrections |
| SSR Code Bias |
| Ephemeris and Clock (if UE did not acquire the navigation message) |

- *PPP-RTK service*: This concept uses precise satellite orbits and clock parameters, the satellite signal biases derived from global networks of Reference Stations as well as ionosphere and troposphere corrections to perform single station positioning IS-QZSS-L6-001 [36]. Therefore, PPP-RTK services compensate the global and local corrections for a more accurate location information. Compared to PPP, PPP-RTK requires the UE to be located within the region covered by the ionosphere and troposphere corrections.

**Table 8.1.2.1a-6: SSR PPP-RTK service: Information that may be transferred from the LMF to the UE**

|  |
| --- |
| **Assistance Data** |
| SSR Orbit Corrections |
| SSR Clock corrections |
| SSR Code Bias |
| Ephemeris and Clock (if UE did not acquire the navigation message) |
| SSR Phase Bias |
| SSR STEC Corrections |
| SSR Gridded Correction |
| SSR URA |
| SSR Correction Points |

8.1.2.1b Mapping of integrity parameters

Table 8.1.2.1b-1 shows the mapping between the integrity fields and the SSR assistance data according to the Integrity Principle of Operation (Clause 8.1.1.1). The corresponding field descriptions for each of the field names listed in Table 8.1.2.1b-1 are specified under Clause 6.5.2.2 of TS 37.355 (LPP).

**Table 8.1.2.1b-1: Mapping of Integrity Parameters**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Error** | **GNSS Assistance Data** | **Integrity Fields** | | | | |
| **Integrity Alerts** | **Integrity Bounds (Mean)** | **Integrity Bounds (StdDev)** | **Residual Risks** | **Integrity Correlation Times** |
| Orbit | SSR Orbit Corrections | Service DNU  Constellation DNU  Satellite Vehicle DNU | Mean Orbit Clock Residual Error Shape Vector  Mean Orbit Clock Residual Rate Error Shape Vector  Mean Orbit Clock Residual Error Scale Factor  Mean Orbit Clock Residual Rate Error Scale Factor | Covariance Orbit Clock Residual Error Shape Matrix  Covariance Orbit Clock Residual Rate Error Shape Matrix  Covariance Orbit Clock Residual Error Scale Factor  Covariance Orbit Clock Residual Rate Error Scale Factor | Probably of Onset of Constellation Fault  Probability of Onset of Satellite Fault | Orbit Range Error Correlation Time  Orbit Range Rate Error Correlation Time |
| Clock | SSR Clock Corrections | Clock Range Error Correlation Time  Clock Range Rate Error Correlation Time |
| Code Bias | SSR Code Bias | Mean Code Bias Error  Mean Code Bias Rate Error | Standard Deviation Code Bias Error  Standard Deviation Code Bias Rate Error |  |
| Phase Bias | SSR Phase Bias | Mean Phase Bias Error  Mean Phase Bias Rate Error | Standard Deviation Phase Bias Error  Standard Deviation Phase Bias Rate Error |
| Ionosphere | SSR STEC Correction  SSR Gridded Correction | Service DNU  Ionosphere DNU | Mean Ionospherre Error  Mean Ionospherre Rate Error | Standard Deviation Ionosphere Error  Standard Deviation Ionosphere Rate Error | Probability of Onset of Ionosphere Fault | Ionosphere Range Error Correlation Time  Ionosphere Range Rate Error Correlation Time |
| Troposphere Vertical Hydro Static Delay | SSR Gridded Corrections | Service DNU  Troposphere DNU | Mean Troposphere Vertical Hydro Static Delay Error  Mean Troposphere Vertical Hydro Static Delay Rate Error | Standard Deviation Troposphere Vertical Hydro Static Delay Error  Standard Deviation Troposphere Vertical Hydro Static Delay Rate Error | Probability of Onset of Troposphere Fault | Troposphere Range Error Correlation Time  Troposphere Range Rate Error Correlation Time |
| TroposphereVertical WetDelay | Mean Troposphere Vertical Wet Static Delay Error  Mean Troposphere Vertical Wet Static Delay Rate Error | Standard Deviation Troposphere Vertical Wet Static Delay Error  Standard Deviation Troposphere Vertical Wet Static Delay Rate Error |

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