# Proposal of New IGS-SSR Ionospheric RMS Message

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## Ionospheric RMS Spherical Harmonic Correction

The global ionosphere Root Mean Square (RMS) Maps provide quality indicators for VTEC corrections through a global spherical harmonic representation. These RMS values are computed using the spherical harmonic basis function as those applied in the VTEC field and serve to quantify the uncertainty or expected error associated with the ionospheric corrections. RMS values are expressed in TECU and are typically used as formal precision indicators for quality assessment and validation. As the mathematical formulation used for vertical RMS (VRMS) representation is identical to that of the VTEC spherical harmonics expansion, the corresponding VRMS computation procedure follows the description provided in Section 4.5.1 of IGS-SSR Format Version 1.00.

The $VRMS$ contribution for each layer is computed in TECU as:

$$VRMS(\varphi_{PP}, \lambda_{PP}) = \sum_{n=0}^{N} \sum_{m=0}^{\min(n,M)} (C_{nm} \cos m\lambda_S + S_{nm} \sin m\lambda_S) P_{nm}(\sin \varphi_{PP})$$

The slant RMS (*SRMS*) contribution of the layer is computed in TECU with

$$SRMS_i = \frac{VRMS}{\sin(E+\psi_{PP})}$$

The angle $\psi_{PP}$ is the spherical Earth's central angle between rover position and the projection of the pierce point to the spherical Earth's surface. It is computed in radians by:

$$\psi_{PP} = {}^{\pi}/_{2} - E - arcsin\left(\frac{R_e+h_R}{R_e+h_I}\cos E\right)$$

| | |
|---|---|
| $E$ | elevation angle of satellite at rover position in the spherical Earth model [radians] |
| $R_e$ | spherical Earth's radius of 6370 km |
| $h_I$ | height of ionospheric layer above the spherical Earth model [km] |
| $h_R$ | height of rover position above the spherical Earth model [km] |

## SSR Ionosphere RMS Spherical Harmonic Message

Table 1 through Table 4 provide the contents the SSR Ionosphere RMS Spherical Harmonics Message. The message consists of header part (Table 1) followed by the model for every individual ionospheric layer (Table 2). Every ionospheric layer model has an Ionosphere RMS Layer Header and two subsequent model parts with Cosine Coefficients (Table 3) and Sine Coefficients (Table 4).

| Data Field | IDF Number | No. of Bytes | No. of Bits | Notes |
|---|---|---|---|---|
| RTCM Message Number | DF002 | uint12 | 12 | Always "4076" for IGS Proprietary Message |
| IGS SSR Version | IDF001 | uint3 | 3 | |
| IGS Message Number | IDF002 | uint8 | 8 | 202 |
| SSR Epoch Time 1s | IDF003 | uint20 | 20 | |
| SSR Update Interval | IDF004 | bit(4) | 4 | |
| SSR Multiple Message Indicator | IDF005 | bit(1) | 1 | |

| Data Field | IDF Number | No. of Bytes | No. of Bits | Notes |
|---|---|---|---|---|
| IOD SSR | IDF007 | uint4 | 4 | |
| SSR Provider ID | IDF008 | uint16 | 16 | |
| SSR Solution ID | IDF009 | uint4 | 4 | |
| VTEC Quality Indicator | IDF041 | uint9 | 9 | |
| Number of Ionospheric Layers | IDF035 | uint2 | 2 | |
| ***TOTAL*** | | | ***83*** | |

**Table 1 : Header Part of the SSR Ionosphere RMS Spherical Harmonics**

For each ionospheric layer follows one section consisting of three parts, one Ionospheric Layer Header Part (Table 2), one block with Cosine Coefficients (Table 3) and one block with Sine Coefficients (Table 4).

| Data Field | IDF Number | No. of Bytes | No. of Bits | Notes |
|---|---|---|---|---|
| Height of Ionospheric Layer | IDF036 | uint8 | 8 | |
| Spherical Harmonics Degree | IDF037 | uint4 | 4 | |
| Spherical Harmonics Order | IDF038 | uint4 | 4 | |
| ***TOTAL*** | | | ***16*** | |

**Table 2 : Header Part for an Ionospheric Layer**

The number of cosine terms of the Cosine Coefficients Part depends on the order and degree of the spherical harmonic expansion. Refer to the corresponding Data Field Note for IDF039.

| Data Field | IDF Number | No. of Bytes | No. of Bits | Notes |
|---|---|---|---|---|
| Spherical Harmonic Coefficient C | IDF039 | int16 | 16 | |
| ***TOTAL*** | | | ***16*** | |

**Table 3 : Model Part of the SSR Ionosphere RMS Spherical Harmonic Cosine Coefficients**

The number of sine terms of the Sine Coefficients Part depends on the order and degree of the spherical harmonic expansion. Refer to the corresponding Data Field Note for IDF040.

| Data Field | IDF Number | No. of Bytes | No. of Bits | Notes |
|---|---|---|---|---|
| Spherical Harmonic Coefficient S | IDF040 | int16 | 16 | |
| ***TOTAL*** | | | ***16*** | |

**Table 4: Model Part of the SSR Ionosphere RMS Spherical Harmonic Sine Coefficients**

## SUB-TYPE MESSAGE SUMMARY

Table 5 is an overview of SSR Ionosphere RMS Spherical Harmonics Sub-Type Message.

| IGM Type | GNSS | IGM Type Name | Sub-Type Mess | Notes |
|---|---|---|---|---|
| - | GNSS | SSR Ionosphere RMS Spherical Harmonics | IM202 | |

| IGM Type | GNSS | IGM Type Name | Sub-Type Mess | Notes |
|---|---|---|---|---|
| | | | IM203 – IM254 | Reserved |

**Table 5: Overview of SSR Ionosphere RMS Spherical Harmonics sub-type messages (IM)**

Table 6 is a list of general IGS SSR Sub-Type Messages, which do not depend on an IGS Generic SSR Message type.

| Sub-Type Message | Message Name | No. of Bytes | Notes |
|---|---|---|---|
| IM202 | SSR Ionosphere RMS Spherical Harmonics | 10.375+2* $N_{IL}$ +2*$N_{HC}$ | $N_{IL}$ = No. of ionospheric layers<br>$N_{HC}$ = No. of Spherical Harmonic Coefficients(total over all ionospheric layers) |

**Table 6: General IGS SSR sub-type messages (IM)**

## Data Field Summary

Table 7 describes the additional data fields required to support the IGS SSR messages. The data field number is prefixed with "IDF" to indicate the IGS SSR relevant data fields. RTCM3 data field numbers are prefixed with "DF".

| IDF # | IDF Name | IDF Range | IDF Resolution | Data Type | Data Field Notes |
|---|---|---|---|---|---|
| IDF001 | IGS SSR Version | 0 – 7 | 1 | unit3 | The IGS SSR Version is part of the sub-framing and is valid for all sub-type messages:<br>0 – experimental<br>1 – 6 Version<br>7 – reserved for extension of version range |
| IDF002 | IGS SSR Message Number | 0 – 254 | 1 | uint8 | IGS RTCM3 Sub-Type Message Number<br>255 – reserved for extension of sub-type message range |
| IDF003 | SSR Epoch Time 1s | 0 – 604799 s | 1 s | uint20 | Full seconds since the beginning of the week of continuous time scale with no offset from GPS, Galileo, QZSS, SBAS, UTC leap seconds from GLONASS, -14 s offset from BDS |
| IDF004 | SSR Update Interval | 0 – 15 | 1 | bit(4) | SSR Update Interval. The SSR Update Intervals for all SSR parameters start at time 00:00:00 of the SSR Epoch Time. A change of the SSR Update Interval during the transmission of a SSR data stream is not allowed. The supported SSR Update Intervals are:<br>0 – 1 s |

| IDF # | IDF Name | IDF Range | IDF Resolution | Data Type | Data Field Notes |
|---|---|---|---|---|---|
| | | | | | 1 – 2 s<br>2 – 5 s<br>3 – 10 s<br>4 – 15 s<br>5 – 30 s<br>6 – 60 s<br>7 – 120 s<br>8 – 240 s<br>9 – 300 s<br>10 – 600 s<br>11 – 900 s<br>12 – 1800 s<br>13 – 3600 s<br>14 – 7200 s<br>15 – 10800 s<br>Note that the update intervals are aligned to the GPS time scale for all GNSS in order to allow synchronous operation for multiple GNSS services. This means that the update intervals may not be aligned to the beginning of the day for another GNSS. Due to the leap seconds this is generally the case for GLONASS. |
| IDF005 | SSR Multiple Message Indicator | 0 – 1 | 1 | bit(1) | Indicator for transmitting messages with the same Message Number and SSR Epoch Time:<br>0 – last message of a sequence<br>1 – multiple message transmitted |
| IDF006 | Global/Regional CRS Indicator | 0 – 1 | N/A | bit(1) | Orbit corrections refer to CRS:<br>0 – ITRF<br>1 – Regional |
| IDF007 | IOD SSR | 0 – 15 | 1 | uint4 | A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration, which may be relevant for rover operation. |
| IDF008 | SSR Provider ID | 0 – 65535 | 1 | uint16 | SSR Provider ID is provided by RTCM on request to identify a SSR service. The Provider ID shall be globally unique. Providers should contact “rtcm.org”.<br>0 to 255 - reserved for experimental services<br>256 to 65535 - unique SSR Provider ID |
| IDF009 | SSR Solution ID | 0 – 15 | 1 | uint4 | SSR Solution ID indicates different |

| IDF # | IDF Name | IDF Range | IDF Resolution | Data Type | Data Field Notes |
|---|---|---|---|---|---|
| | | | | | SSR services of one SSR provider |
| IDF035 | Number of Ionospheric Layers | 0 – 3 ($N_{IL}$: 1 – 4) | 1 | uint2 | Number of Ionospheric Layers -1 ($N_{IL}$-1). The VTEC spherical harmonics model consists of one or more infinitesimal thin ionospheric layers. |
| IDF036 | Height of Ionospheric Layer | 0 – 2550 km | 10 km | uint8 | Height of the ionospheric layer |
| IDF037 | Spherical Harmonics Degree | N-1: 0 – 15 (N: 1 – 16) | 1 | uint4 | Degree-1 (N-1) of spherical harmonic expansion of global ionosphere in latitude |
| IDF038 | Spherical Harmonics Order | M-1: 0 – 15 (M: 1 – 16) | 1 | uint4 | Order-1 (M-1) of spherical harmonic expansion of global ionosphere in longitude (local time) |
| IDF039 | Spherical Harmonic Coefficient C | ± 163.835 TECU | 0.005 TECU | int16 | Cosine parameters of spherical harmonics expansion of degree N and order M. The number of cosine parameters is: $\frac{(N+1)(N+2)}{2} - \frac{(N-M)(N-M+1)}{2}$ 163.84 indicates data out of range or not available. |
| IDF040 | Spherical Harmonic Coefficient S | ± 163.835 TECU | 0.005 TECU | int16 | Sine parameters of spherical harmonics expansion of degree N and order M. The number of sine parameters is: $\frac{(N+1)(N+2)}{2} - \frac{(N-M)(N-M+1)}{2} - (N+1)$ -163.84 indicates data out of range or not available. |
| IDF041 | VTEC Quality Indicator | 25.55 TECU | 0.05 TECU | uint9 | VTEC quality indicator for vertical ionospheric effect not described by the spherical harmonic expansions.<br>0 – unknown<br>25.55 – indictor exceeds 25.54 TECU |