IGS State Space Representation (SSR) Format

Version 1.00

International GNSS Service (IGS)

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ACRONYMS

ANTEX	Antenna Exchange Format
APC	Antenna Phase Center
ARP	Antenna Reference Point
BDS	BeiDou System
CORS	Continuous Operating Reference Station
CPB	Code Phase Bias
CRS	Coordinate Reference System
CoM	Center of Mass
DCB	Differential Code Bias
DF	Data Field (from RTCM)
ECEF	Earth Centered Earth Fixed
ETRF	European Terrestrial Reference System
FDMA	Frequency Division Multiple Access
GDV	Group Delay Variation
GEO	Geostationary Earth Orbit
GF	Geometry Free
GLONASS	Russian GNSS: Globalnaja Nawigazionnaja Sputnikowaja Sistema
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
Galileo	European GNSS
ICD	Interface Control Document
ID	Identifier
IDF	IGS Data Field
IERS	International Earth Rotation and Reference Systems Service
IF	Ionosphere Free
IGM	IGS Generic SSR Message
IM	IGS SSR sub-type Message
IOD	Issue of Data
IODN	Issue of Data Navigation
IRNSS	Indian Regional Navigation System NAVIC
ITRF	International Terrestrial Reference Frame
LC	Linear Combinations
LSb	Least Significant bit
MSb	Most Significant bit
MT	Message Type (from RTCM)
MW	Melbourne-Wübbena (linear combination)
NavIC	Navigation with Indian Constellation (IRNSS)
NSRS	National Spatial Reference System
PCO	Phase Center Offset
PCV	Phase Center Variation
PHR	Phaserange
PPP	Precise Pont Positioning
PR	Pseudorange
QZSS	Quasi-Zenith Satellite System
RINEX	Receiver Independent Exchange format
RT	Real-Time
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services

RTK	Real-Time Kinematic
SBAS	Satellite Based Augmentation System
SC	Special Committee
SRP	Satellite Reference Point
SSR	State Space Representation
STEC	Slant TEC
SV	Space Vehicle
TEC	Total Electron Content
TECU	TEC Unit
URA	User Range Accuracy
VTEC	Vertical TEC
WG	Working Group

0. REVISION HISTORY

	Version 1.00
05 Oct 2020	Release Version

1. THE PHILOSOPHY AND HISTORY OF IGS SSR

The need for standardization of a State Space Representation (SSR) Global Navigation Satellite System (GNSS) correction data format has been identified many years ago, when the International GNSS Service (IGS) developed and analyzed Precise Point Positioning (PPP) techniques and the industry proposed the use of PPP-RTK technology. In RTCM (Special Committee) SC-104, a working group was established in 2007. The SSR technology is widely considered to be the future, flexible GNSS correction approach, as it has the advantage of scalability in terms of supporting an unlimited number of users, different types of applications as well as support of the large variety of modern GNSS, frequencies and signals.

The RTCM-SSR WG defined the development of SSR concepts and real-time capable messages for all types of accuracies, including ambiguity resolution (RTK quality). The proposed schedule or work plan consisted of the following major steps:

- stage 1 with satellite orbit, satellite clock and satellite code bias messages
  to enable code-based Real-Time (RT)-PPP for dual-frequency receivers
- stage 2 with vertical Total Electron Content (VTEC) ionospheric message
  to enable code-based RT-PPP for single frequency receivers and satellite phase bias messages to enable phase-based RT-PPP
- stage 3 with ionospheric slant TEC (STEC) and tropospheric messages
  to enable PPP-Real-time-Kinematic (RTK)
- stage 4 with compression to reduce bandwidth

The concept of SSR requires the transmission of a bias (code or phase bias) for every supported signal. Signals with no bias information are unsupported and should not be used by receiving applications.

Standardized RTCM-SSR Messages for GPS and GLONASS were first published in ”RTCM STANDARD 10403.1 with Amendments 1-5, July 1, 2011”. Only RTCM stage 1 messages have so far been standardized and out of those, only the ones that cover GPS and GLONASS.

The format was developed to be general and flexible to support different GNSS SSR estimation and modeling approaches. Accordingly, the initial focus was put on the content of the messages, shifting bandwidth optimization (compression) to the last development stage. In the meantime, the general validity of the concept and the mapping of known modeling approaches have been demonstrated in theory and practice.

The IGS has developed and published this standard with stage 1 and 2 messages for multi-GNSS SSR correction dissemination. This is an open format that can be used by the wider community, but in particular to support the IGS real-time service as well as broader research and scientific application. Although a different message format is used, the basic contents of the IGS-SSR representation are compatible with RTCM-SSR contents.

The IGS SSR format is an open standard for dissemination of real-time products to support the IGS Real-Time Service and the wider community. The messages support multi-GNSS and include corrections for orbits, clocks, code-biases resp. Differential Code Biases (DCBs), phase-biases and ionospheric delays. Extensions to also cover satellite attitude, phase center offsets and variations and group delay variations are planned in the near future. The goal is to create a self-contained and scalable standard for a wide range of real-time applications.

2. GENERAL FORMAT DESCRIPTION

The IGS SSR binary format uses the basic structure of RTCM3 developed by the RTCM SC-104. For information on the general transport layer refer to the RTCM 10403.3 Standard.

An IGS SSR data stream consists of different message types:

- IGS RTCM Proprietary SSR messages
- Standardized RTCM 10403.3 messages (non SSR)

RTCM proprietary message types are assigned to specific companies and organizations in the RTCM 10403.3 Standard for the broadcast of proprietary information. The format of the proprietary messages corresponds to the RTCM messages, in that the transport layer is defined in the same way, and the first data field is a 12-bit message number for an organization. The organization is free to define several sub-types of messages, but they must all utilize the assigned message type.

The IGS RTCM Proprietary SSR messages uses the IGS assigned RTCM proprietary message type:

Message Type	Organization	Contact
4076	International GNSS Service (IGS)	www.igs.org

Within the IGS Proprietary SSR Messages several sub-types of messages are defined, and they all utilize the IGS assigned RTCM3 message type “4076”.

Within this document the term “shall” expresses a required specification. The term “should” is dealt with as a recommendation.

3. BASIC DEFINITIONS

The principle of the state space concept is to provide information on individual error sources acting on GNSS to enable an improved positioning for a user. Therefore, the term “State Space Representation” is used.

The GNSS state vector of SSR consists of the following basic parameters:

- satellite orbit errors
- satellite clock errors
- satellite signal biases
- ionospheric propagation delays and advances
- tropospheric delays

Satellite orbit and clock errors are corrections to the broadcast information provided by a GNSS. Satellite signal biases are delays to codes and carrier phases observations within satellite hard- and software. The GNSS signals are affected by atmospheric propagation delays due to the ionosphere and the troposphere.

The software system used to generate SSR corrections must apply different corrections due to effects like reference station site displacements, relativity, phase wind-up, satellite and receiver antenna phase center variations (PCVs) and group delay variations (GDVs), atmospheric delays and others to the used GNSS observations. The estimated SSR parameters are then free of such effects. Depending on the quality of the service, a client application (rover) must apply corresponding corrections when using SSR parameters in order to determine its position in a conventional coordinate system.

An SSR application may consider correction models e.g. for:

- coordinate frame transformation to account e.g. for tectonics (transformation from global to continental frames and vice versa)
- solid Earth tides
- ocean loading
- atmospheric pressure loading
- rotational deformation due to polar motion (e.g. pole tide)
- relativistic effects
- satellite phase wind-up
- satellite antenna code and phase center variations

Reference for correction and correction models are the latest IERS Conventions and Wu et al. (1991) for satellite phase wind-up.

4. SSR REPRESENTATION MODELS

Consistency of data and processing is an important concept of SSR. In order to allow bandwidth optimization and depending on their temporal characteristics different SSR parameters can be determined for different update intervals. The generating process must ensure the consistency of SSR parameters utilizing the Update Intervals. A receiving process must collect the relevant SSR parameters from different Update Intervals in order to obtain consistent sets of corrections. The meaning of SSR Update Interval is different from the transmission interval/rate of SSR messages. The validity interval of SSR parameters is at least the SSR Update Interval.

A state space parameter may consist of different constituents disseminated in different SSR correction messages. The use of different SSR messages is intentional to support different applications, update rates and accuracy requirements. Additional SSR correction messages will consequently add additional resolution and positioning accuracy. This creates the need to know the consistency of the SSR parameters for an application. Only a consistent set of SSR parameters can build up a complete and accurate correction. The consistency of SSR data becomes more important with increasing resolution provided by additional SSR correction messages.

Generally, the continuous chronology of messages can be used to check the consistency, but in real-time applications messages may be lost or delayed. A consistency parameter is also the GNSS specific Issue of Data (IOD), which is used to obtain consistency in the computation of SSR orbit and clock corrections. A similar requirement exists for state space parameters distributed over several SSR messages.

There are several SSR Update Intervals defined, which all start at the start of a day in the SSR time scale (time: 00:00:00). The SSR message contains the SSR Epoch Time 1 s data field (IDF003). The consistency of the SSR parameters can be verified from this information. The rover is then capable to combine all relevant SSR parameters consistently and it secures the combination of state parameters from different messages.

The SSR Update Interval serves to uniquely identify all consistent parameters from different messages, which can be used to compute consistent corrections at one epoch.

The reference time for the correction terms is computed from the SSR Epoch Time 1 s data field (IDF003) plus half the SSR Update Interval. Exception is SSR Update Interval “0”, which uses the SSR Epoch Time as reference time.

GNSS IOD information of broadcast clocks is redundant and is not required in addition to the broadcast orbit IOD. I.e., the SSR Orbit and Clock corrections refer to the same IOD. The service provider should refer to the latest set of broadcast messages, which are generally also received in real-time by a GNSS rover. However, it is recommended to delay the use of the latest broadcast message for a period of 60 seconds, measured from the time of complete reception of ephemeris and clock parameters, in order to accommodate rover applications to obtain the same set of broadcast orbital and clock parameters. It is left to the service provider to send the RTCM Satellite Ephemeris Data (e.g. Message Types (MT)1019 for GPS and MT1020 for GLONASS) before switching to a new IOD. It is not allowed to send corrections for more than one IOD for the same orbit Update Interval. The consistency of SSR Orbit and Clock messages is maintained through the SSR Update Interval.

4.1 SSR Satellite Orbit Correction

The SSR orbit correction messages contain parameters for orbit corrections in radial, along-track and cross-track components.

The orbit and clock messages contain data to be combined with the corresponding values obtained from the satellites broadcast message. See Table 1 for the type of broadcast navigation messages used per individual GNSS.

GNSS	Broadcast Message Type
GPS	NAV data, D(t)
GLONASS	GLONASS M data
Galileo	I/NAV data
SBAS	NAV data, D(t)
BDS	D1 NAV/D2 NAV data
QZSS	NAV data, D(t)

Table 1 : Specification of Broadcast message type used for GNSS SSR orbit and clock correction

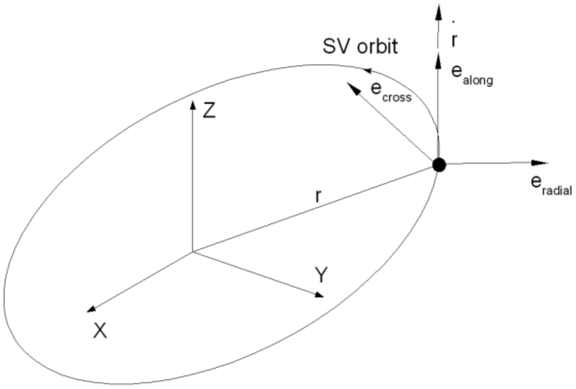

Figure 1 : Radial, along-track and cross-track orbit components

The Orbit Correction Message contains the parameters for orbit corrections $\delta\boldsymbol{O}$ in radial, along-track and cross-track component. These orbit corrections are used to compute a satellite position correction $\delta\boldsymbol{X}$, to be combined with satellite position $\boldsymbol{X}_{broadcast}$ calculated from broadcast ephemeris. The sign definition of the correction is

$$\boldsymbol{X}_{orbit} = \boldsymbol{X}_{broadcast} - \delta\boldsymbol{X}$$

with

$\boldsymbol{X}_{orbit}$	satellite position corrected by SSR Orbit Correction message
$\boldsymbol{X}_{broadcast}$	satellite position computed according to corresponding GNSS Interface Control Document (ICD) from broadcast ephemeris parameter set identified by the GNSS IOD in SSR Orbit Correction message
$\delta\boldsymbol{X}$	satellite position correction

The satellite position correction $\delta\boldsymbol{X}$ is computed according to

$$\boldsymbol{e}_{along} = \frac{\dot{\boldsymbol{r}}}{|\dot{\boldsymbol{r}}|}$$
$$\boldsymbol{e}_{cross} = \frac{\boldsymbol{r} \times \dot{\boldsymbol{r}}}{|\boldsymbol{r} \times \dot{\boldsymbol{r}}\,|}$$
$$\boldsymbol{e}_{radial} = \boldsymbol{e}_{along} \times \boldsymbol{e}_{cross}$$
$$\delta\boldsymbol{X} = [\boldsymbol{e}_{radial} \quad \boldsymbol{e}_{along} \quad \boldsymbol{e}_{cross}]\ \delta\boldsymbol{O}$$

with

$\boldsymbol{r} = \boldsymbol{X_{broadcast}}$	Earth Centered Earth Fixed (ECEF) satellite broadcast position vector
$\dot{\boldsymbol{r}} = \dot{\boldsymbol{X}}_{\boldsymbol{broadcast}}$	ECEF satellite broadcast velocity vector
$\boldsymbol{e}_i$	direction unit vector, i = {radial, along, cross}
$\delta\boldsymbol{O}$	orbit correction vector

Note: The radial vector $\boldsymbol{e}_{radial}$ is used in the computation and should not be confused with a radial vector of a circular orbit.

The complete orbit correction vector $\delta\mathrm{O}$ is computed from the individual correction terms and their velocities:

$$\delta\boldsymbol{O} = \begin{bmatrix} \delta O_{radial} \\ \delta O_{along} \\ \delta O_{cross} \end{bmatrix} + \begin{bmatrix} \delta\dot{O}_{radial} \\ \delta\dot{O}_{along} \\ \delta\dot{O}_{cross} \end{bmatrix} (t - t_0)$$

with

t	time
t_0	reference time obtained from SSR Orbit Correction message
$\delta O_i, \delta\dot{O}_i$	orbit correction terms from SSR Orbit message, i = {radial, along, cross}

The ECEF satellite broadcast velocity vector for Geostationary Earth Orbit satellites (GEO) can be null, which gives no SSR orbit corrections using the above set of equations. The velocity vector for GEO satellites is therefore defined in a non-rotating system parallel to the International Terrestrial Reference Frame (ITRF) at SSR epoch time. The GPS value of the angular velocity of the Earth around the Z-axis is used.

$$\dot{\Omega}_e = 7.2921151467\ 10^{-5}\ \mathrm{rad/sec}$$

$$\dot{r} = \dot{r}_{broadcast} + \begin{bmatrix} -\dot{\Omega}_e \cdot Y_{broadcast} \\ \dot{\Omega}_e \cdot X_{broadcast} \\ 0 \end{bmatrix}$$

with

$\dot{\Omega}_e$	angular velocity of the Earth around the Z-axis
$\dot{r}_{broadcast} = \dot{X}_{broadcast}$	satellite broadcast velocity vector (ECEF)

Orbit representation requires the definition of a Coordinate Reference System (CRS). For global services, the CRS should be related to the International Terrestrial Reference System (ITRS). For regional services, a CRS related to the tectonic plate of the region can be used. Such continental or regional CRS (e.g. European Terrestrial Reference System (ETRF), Canadian Spatial Reference System (CSRS), National Spatial Reference System (NSRS), etc) adopt coordinate reference frames close to the ITRF at a certain epoch. They drift away over time due to the tectonic movement of the continental plates. The GNSS SSR orbit correction messages allow transmission of orbit corrections in continental/regional CRS. In this case, it is not necessary for the rover to perform the corresponding transformation. A regional datum is indicated by the Global/Regional CRS Indicator, while the actual CRS will be identified by the configured stream of the service provider or the RTCM Service CRS message.

Note: Using a regional coordinate system may result in degraded performance if the CRS has a large scale factor (relative to ITRF).

The satellite orbit corrections must refer to a Satellite Reference Point (SRP). The satellite orbit may be provided with respect to the satellite Center of Mass (CoM) or the Antenna Phase Center (APC) of a specific carrier frequency.

When using APC, the SRP should be the average APC of the corresponding carrier frequency. In the past, the APCs and PCVs for GPS and GLONASS L1, L2 frequencies have been treated as being identical to the APC and PCV of the L1/L2 ionospheric free linear combination (L0), i.e. APC(L1) = APC(L2) = APC(L0).

With the availability of new constellations, frequencies, and calibration procedures, a different definition is necessary. For IGS-SSR the SRP is the APC of a primary frequency per GNSS (see below Table 2). This approach avoids the definition of a specific linear combination and is compatible with the old definition for GPS and GLONASS (L1 and L2 identical to L0).

If the SRP is not the CoM, the SRP for orbit corrections is the antenna phase center (APC) of the reference frequency as listed in Table 2.

The SSR generation system shall correct all observations for receiver and satellite antenna PCVs and GDVs.

GNSS	APC of Reference Frequency
GPS	L1
GLONASS	G1
Galileo	E1
SBAS	L1
BDS	B1-2
QZSS	L1
NavIC/IRNSS	L5

Table 2 : GNSS APC SRP Definition

Antenna Phase Center Offset (PCO), PCV and GDV corrections for satellite and receiving antennae need to be applied to GNSS observations as a function of line of sight from the satellite to a receiving antenna. These values can be extracted from ANTEX files available from the IGS. The corrected observations will then refer to the antenna reference points at both the satellite and ground antenna (ARP).

Services using the IGS SSR format can refer to either the satellite CoM or the average APC of a GNSS specific reference frequency (see Table 2).

For an APC reference a user needs to correct for PCO, PCV and GDV as a function of nadir angle and azimuth (in the satellite reference frame) by utilizing frequency dependent correction tables. To do that, the PCOs as given in the satellite antenna correction for all frequencies have to be reduced by the PCO of the reference frequency. Fortunately, the azimuth dependent satellite PCVs are expected to be small (in the order of 1 mm) and can thus be neglected for most applications. The correction of PCV and GDV therefore requires only the nadir distance of the ray to the receiving antenna. This angle can be computed without knowledge of the correct satellite attitude model.

For APC related services the IGS Generic SSR Messages (IGM001-IGM007) are sufficient for successful and interoperable operation. It is recommended to use antenna corrections from the most recent IGS antenna correction model (e.g. igs14.atx file).

In case of services utilizing the CoM as SRP, additional information and computation is required on the client side. The APC referenced observations must be corrected by the CoM-APC offset vector. Since these offsets can amount to meters for the Z-offset and several decimeters for the X/Y offsets for some satellite types, an azimuth dependency is present. This requires the knowledge of the correct attitude of the satellite. It should be noted that the correct yaw angle of the satellite might not be accessible at all times.

In order to allow consistent and interoperable services utilizing CoM as SRP, IGS SSR messages to transport the full satellite attitude with reliability flags as well as the CoM/APC offsets are required. Such messages are under development.

4.2 SSR Satellite Clock Correction

The SSR orbit corrections are corrections to be applied to the satellite orbit as computed from satellite broadcast parameters with the corresponding GNSS-ICD algorithm. In the same sense, the SSR satellite clock corrections are to be applied to the satellite clock as computed from the GNSS specific satellite broadcast parameters with the corresponding GNSS-ICD algorithm. The SSR corrections are not defined as corrections to any GNSS specific broadcast correction term itself (i.e. the corrections C_i are not directly related to the GPS clock correction terms a_i nor to the GLONASS clock bias (τ_n) or frequency offset (γ_n) corrections terms).

The SSR clock correction message contains the parameters to compute the clock correction δC applied to the broadcast satellite clock. The polynomial representation describes the clock differences for a certain time period. The sign definition of the corrections is

$$t_{satellite} = t_{broadcast} - \frac{\delta C}{Speed\ of\ light}$$

with

$t_{broadcast}$	satellite time computed according to corresponding GNSS ICD from broadcast clock parameters, identified by the GNSS IOD of corresponding SSR Orbit Correction message
$t_{satellite}$	satellite time corrected by SSR Clock Correction message
δC	clock correction obtained from SSR Clock Correction message

The polynomial is computed according to

$$\delta C = C_0 + C_1(t - t_0) + C_2(t - t_0)^2$$

with

t	time
t_0	reference time obtained from SSR Clock Correction message
C_i	polynomial coefficients from SSR Clock Correction message, i = {0, 1, 2}

A High Rate Clock SSR message supports higher resolution of the clock state and higher update rates. Both constituents, Clock Message and High Rate Clock Message, define the complete state of the satellite clock. The High Rate Clock correction is added to the corresponding clock correction.

The complete SSR clock correction term δC (refer to RTCM 10403.3) with the High Rate Clock correction term reads

$$\delta C = C_0 + C_1(t - t_0) + C_2(t - t_0)^2 + \delta C_{High\ Rate}$$

with

δC	clock correction obtained from SSR Clock Correction message
C_i	polynomial coefficients from SSR Clock Correction message, i = {0, 1, 2}
t	time
t_0	reference time obtained from SSR Clock Correction message
$\delta C_{High\ Rate}$	high rate clock correction term from SSR High Rate Clock message

Satellite clocks are determined from ionospheric free signals derived from observations used by the service provider. Such observations are affected by delays introduced in the satellite hardware (code biases). For example, GPS broadcast clocks are referenced to the ionospheric free linear combination of the P codes on L1 and L2, ignoring any code biases of these signals. For SSR, the selection of signals used to generate the satellite clock corrections and the treatment of code biases are left to the service provider. The service provider shall ensure a consistent transmission of clock and code bias parameters. A rover must then consistently apply the code biases and clock corrections.

4.3 SSR Satellite Bias Corrections

Generally, every signal component transmitted by a GNSS satellite experiences an individual time dependent bias as a function of hard- and software delays. In the GNSS pseudorange (PR) and phaserange (PHR) (carrier phase) observation equation there is a linear dependency between the individual satellite signal biases and the satellite clock error. A full separation of all bias and clock parameters within an estimation process is thus not possible. One solution to overcome this problem is the definition of a “Satellite Bias Datum” which sets the bias of a certain signal or linear combination of signals to zero. The GPS broadcast clock corrections, for example, are based on the definition that the ionospheric free linear combination of the P1 and P2 code signals (RINEX observation codes C1P and C2P) is bias free. A similar convention is used by the IGS for their clock products. Applying a Bias Datum will transform all remaining biases to relative biases with respect to the Bias Datum.

In order to avoid Bias Datum conventions for the definition of the SSR standards, the SSR satellite bias correction messages contain absolute signal biases. I.e., for each supported signal component, a bias parameter needs to be transmitted. This increases the number of bits required for one additional parameter but provides maximum flexibility for a service provider to select supported signals and Bias Datum definitions. The code and phase bias messages contain absolute values, but also enable the alternative use of DCBs by setting one of the biases to zero.

In the literature it is sometimes stated that more than one bias can be omitted or set to zero because it cannot be distinguished from the ionospheric effect. However, this is only true if the ionosphere is treated or modeled as an individual satellite dependent line of sight bias. In case of more sophisticated ionospheric modelling this assumption no longer holds. With respect to this, note the Dispersive Bias Consistency Indicator in the SSR phase bias messages.

It is further stated sometimes that phase biases can be omitted because they cannot be distinguished from phase ambiguities. This however only holds for applications where no ambiguity resolution is intended and only for short periods of time because a carrier phase ambiguity is constant over time, but the phase bias is not (varies with temperature).

An ideal SSR generation process would rigorously estimate all SSR parameters consistently from all observations of a continuously operating reference stations (CORS) network utilizing an adequate filtering or adjustment tool. All pseudorange and phaserange observations would be processed simultaneously to estimate all geometric (mainly orbits, clocks, troposphere, receiver clocks and site coordinates) as well as dispersive (ionosphere) parameters plus all satellite and receiver dependent signal biases and carrier phase ambiguities. Practically such a system is difficult to implement, due to the very high number of unknown parameters as well as usually very high number of observations. Furthermore, the formulation of functional and stochastic models is a challenging task.

To overcome these problems, different strategies to reduce the number of parameters and/or observations to be processed are in use. One strategy is the processing of linear combinations of observations. For example, the observation equation for the ionosphere free (IF) linear combinations (LC) of observables does not contain ionospheric parameters and their usage can thus drastically reduce the number of unknowns. On the other hand, geometry free (GF) linear combinations do not depend on geometric parameters and allow the estimation of ionospheric models. Linear combinations with both IF and GF property (IF+GF) only depend on signal biases and carrier phase ambiguities. One important application for the IF+GF linear combinations is the ambiguity resolution for wide lanes, often called the Melbourne-Wübbena (MW) linear combination.

Any linear combination of observations contains the corresponding linear combination of satellite and receiver signal biases. The SSR generating process must take care that the satellite signal biases are consistent with all the other SSR parameters, especially if the SSR stream is a combination of the results from different partial filters or adjustments.

For example, after correcting the observations of a client application (rover) with the received SSR signal biases (and phase wind-up and antenna PCO/PCV), different IF LCs of PR and/or PHR observations can be computed for dual- or multi-frequency observations. Except for a common bias for all satellites with the same LCs, remaining carrier phase ambiguities and estimation and observation inaccuracies, all such IF LCs shall provide the same geometric (IF) PR/PHR. Hence, a plot of between satellites single differenced and time differenced values of the difference of two such IF LCs shall not contain any bias or ambiguity, but just observation and estimation noise and remaining multipath effects.

Similarly, different GF LCs as difference between two corrected PR or PHR of different frequencies or difference of a PHR and PR and scaled with the corresponding frequency dependent factors for first order ionosphere shall provide the same ionosphere, except for a common bias for all satellites with the same LCs, remaining carrier phase ambiguities and estimation and observation inaccuracies. A plot of between satellites single differenced and time differenced values of the difference of two such GF LCs shall not contain any bias or ambiguity, but just observation and estimation noise and remaining multipath effects.

Note that in both examples above uncorrected higher order ionospheric effects may also cause some differences.

The usage of single or double differences is another example for the reduction of the number of parameters in the system. The consistency requirement holds here if the results of corresponding filters are combined with non-differenced results within the same SSR stream.

Depending on the processing model, SSR services may differ concerning the properties of the estimates for satellite signal biases.

The phase bias messages contain two consistency indicators (MW Consistency Indicator and Dispersive Bias Consistency Indicator).

The MW Consistency Indicator indicates the coherent use of code and phase biases for MW LCs. If this indicator is set to 1, the MW combination of observations corrected by the transmitted code and phase biases are bias free (except for a common bias for all satellites) and thus can be used to determine the integer wide-lane ambiguity directly.

The Dispersive Bias Consistency Indicator shall be set to zero (0) if the corrected client PR and PHR may contain arbitrary ionosphere because the service providers Satellite Bias Datum constrains not only one but two biases. A client application cannot assume to obtain true ionosphere after applying bias corrections to its observations. True slant TEC (STEC) is e.g. required to compute higher order ionosphere corrections.

The satellite code and phase bias message use a GNSS Signal and Tracking Mode Identifier to describe the actual signal properties. The GNSS Signal and Tracking Mode Identifier maps the RINEX 3.x observation types into a more compact storage scheme of integer indices. The RINEX observation types use type (code, carrier, etc.), band (L1, L2, etc.) and attribute (tracking mode). The band and tracking mode attribute are required to account for the variety of signal tracking.

The yaw angle is used for computation of phase wind-up correction (Wu et al. 1993). The yaw angle describes the angle between the yaw origin and the satellites x-axis as a positive rotation around the nadir-pointing z-axis.

The user shall not assume that the yaw angle describes the true orientation of the satellite. Yaw is provided only for consistent computation of phase wind-up corrections. The service provider must choose an appropriate satellite yaw model to ensure consistent and continuous provision of satellite clock correction, code and phase biases and yaw angle. A yaw of 0 (zero) is a valid value and shall be applied for the wind-up correction by users receiving it. Since the provided yaw angle may not describe the true satellite yaw, the yaw cannot safely be used to convert CoM to SRP orbits or vice versa.

For the effective use of satellite phase biases any discontinuities and the integer property of the phase bias are of interest. The discontinuity and integer property of the phase biases is reported for every satellite phase signal.

In addition to the satellite phase signals, the integer property of wide-lane linear combinations is reported for up to three groups. The wide-lane groups simplify the bookkeeping of resolved wide-lanes. Each one of the pair of signals of a resolved wide-lane is assigned to the same group. With every satellite frequency the number of wide-lanes combinations increases. For two or three frequencies one group, for four or five frequencies two groups and for six frequencies at most three groups are required to track the possible different wide-lane combination. For details refer to IDF030.

It should be noted that due to the linear dependency of satellite and receiver biases, the SSR biases of a specific signal for all satellites may have a common time varying offset (bias), which affects the estimate of the corresponding rover receiver bias but does not harm the positioning solution. Such common offsets/biases may behave different from physical receiver biases. Especially the time variations may be larger than physical bias variations and may not be continuous. A rover application should thus not make any assumption about the variation of common biases or correlation of common biases for different signals.

A special consideration is necessary for GLONASS frequency division multiple access (FDMA) signals. The GLONASS receiver dependent Code Phase Biases (CPB) are important in conjunction with carrier phase ambiguity resolution. The service provider shall ensure that for all processed GLONASS FDMA observations the CPBs are corrected before generating GLONASS satellite phase bias estimates. Furthermore, the FDMA code biases may contain significant satellite or channel dependent individual contribution. The magnitude of such individual biases is highly dependent on the signal tracking hard- and software, i.e. the antenna, receiver type and firmware. In case of a network with mixed CORS types, the service provider is responsible for the correct handling of different individual satellite/channel biases from different tracking hard- and software. If the remaining “service” biases can be leveled to a certain tracking hardware and software, the service provider may indicate this through a standard RTCM MT1033 “Receiver and Antenna Descriptor”.

The provider shall support as many signals as possible and must report biases for all supported signals even if they are zero and/or used as Bias Datum. A rover can consistently use signals for which a bias is transmitted. It is not reliable for a rover to use a signal without retrieving a corresponding bias from the data stream. The coherent use of code and phase signals relies on the availability of information for both phase and code biases.

The sign definition for the biases reported in the SSR satellite bias messages is that the biases should be added to the PR or PHR measurements of the corresponding signal to get corrected ranges.

4.4 SSR URA

Individual state parameters are not independent. Clock and radial orbit state parameters, for example, are correlated. An SSR User Range Accuracy (URA) is used as one single statistical indicator to describe the quality of all non-dispersive state parameters. The SSR User Range Accuracy is transmitted in an SSR URA message per satellite. A special formula is used to enable high resolution for small numbers and low resolution for large numbers.

4.5 SSR Ionosphere

4.5.1 Ionosphere Vertical TEC

The Ionosphere Vertical TEC (VTEC) is provided using spherical harmonic expansions. A spherical harmonic expansion allows a global and continuous model of the ionosphere but can also be applied to regional representation. It is the first constituent of a multiple stage ionospheric correction.

The VTEC from the spherical harmonic expansion is defined for infinitesimal thin TEC layers. The values must be mapped to slant TEC (STEC) values using the elevation of the satellites at the height of the corresponding ionospheric layer transmitted in the SSR VTEC message (see below).

Note: A spherical harmonic expansion with high degree and order may suffer a weak representation of the true VTEC in areas with weak observation coverage. It is the responsibility of the service provider to take countermeasures to avoid unreasonable VTEC values. Negative VTEC values must be ignored by the rover and shall be replaced by 0.0.

In order to simplify the algorithm and to avoid heavy computational load, the spherical harmonics are defined for a spherical Earth model, with a mean radius of 6370 km. Latitude, longitude, height as well as azimuth and elevation of the satellites are defined with respect to this model instead of an ellipsoidal representation.

Note: For the computation of the ECEF satellite position's azimuth and elevation, the ECEF satellite coordinates computed at the time of signal transmission at the satellite shall be rotated to the epoch of signal reception at the receiver to account for the Sagnac effect caused by Earth rotation and signal propagation.

The cosine coefficients C and sine coefficients S are represented for a specific degree N and order $M \leq N$ of a series of spherical harmonic functions to describe the VTEC in total electron content units (TECU) (1 TECU = $10^{16} \frac{electrons}{m^2}$).

The VTEC contribution for each layer is computed in TECU as:

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

with

N	degree of spherical expansion
M	order of spherical expansion
n, m	indices
C_{nm}	cosine coefficients for the layer [TECU]
S_{nm}	sine coefficients for the layer [TECU]
λ_S	mean sun fixed and phase shifted longitude of ionospheric pierce point for the layer modulo 2π [radians]
λ_{PP}	longitude of ionospheric pierce point for the layer [radians]
t	SSR epoch time of computation epoch modulo 86400 [s]
φ_{PP}	geocentric latitude of ionospheric pierce point for the layer [radians]
$P_{nm}()$	fully normalized associated Legendre functions

The mean sun fixed longitude phase shifted by 2 h to the approximate TEC maximum at 14:00 local time (resp. 50400 s) is computed by:

$$\lambda_S = \left(\lambda_{PP} + (t - 50400) * {}^{\pi}/_{43200}\right) \, modulo \; 2\pi \, .$$

Longitude λ_{PP} and latitude φ_{PP} refer to the position of the ionospheric pierce point at the height of the ionospheric layer. The ionospheric pierce point is the intersection of a straight line from the rover position to the satellite and a sphere with the height of the ionospheric layer above the spherical Earth model.

The position of the pierce point in the spherical Earth model is computed in radians, for example, by:

$$\varphi_{PP} = arcsin(sin\,\varphi_R \cos\psi_{PP} + \cos\,\varphi_R\, sin\,\psi_{PP} \cos A)$$

with

φ_R	geocentric latitude of rover position [radians]
λ_R	longitude of rover position [radians]
ψ_{PP}	central angle of the pierce point [radians]
A	azimuth of satellite from rover position in the spherical Earth model [radians]

The angle ψ_{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]

Under the following conditions, which apply for rover position and satellites visible at rover position

$\varphi_R \geq 0°$ and $\tan\psi_{PP}\cos A > \tan\left({}^{\pi}/_{2} - \varphi_R\right)$

or

$\varphi_R < 0°$ and $-\tan\psi_{PP}\cos A > \tan\left({}^{\pi}/_{2} + \varphi_R\right)$

the pierce point longitude is computed in radians according to

$$\lambda_{PP} = \lambda_R + \pi - \arcsin\left(\frac{\sin\psi_{PP}\sin A}{\cos\varphi_{PP}}\right)$$

In all other cases the pierce point longitude is computed in radians according to

$$\lambda_{PP} = \lambda_R + \arcsin\left(\frac{\sin\psi_{PP}\sin A}{\cos\varphi_{PP}}\right)$$

The STEC contribution of the layer i is computed in TECU with

$$STEC_i = \frac{VTEC}{\sin(E+\psi_{PP})}$$

The total STEC is computed by the sum of the individual STECi for each layer i.

The influence of the ionosphere on the observations for a specific frequency f [Hz] is a pseudorange delay in m:

$$\delta PseudoRange\,(f) = \left({}^{40.3}\!/_{f^2} * STEC * 10^{\,16}\right)$$

or a phaserange advance in m:

$$\delta PhaseRange\,(f) = -\left({}^{40.3}\!/_{f^2} * STEC * 10^{\,16}\right)$$

5. DATA TYPE SUMMARY

RTCM3 uses different data types for the fixed data field in the messages. The following data types in Table 3 are an extension of the Data Type Table in the RTCM 10403.3 Standard, which are required to support the IGS SSR messages. Note that floating point quantities are not used.

Data Type	Description	Range	Data Type Notes
none			

Table 3 : IGS SSR data types

6. SUB-TYPE MESSAGE SUMMARY

The IGS SSR data is organized in different messages according to the different SSR parameters. Table 4 describes IGS Generic SSR Messages (IGM) types applicable for different GNSS. IGS SSR Sub-Type Messages are defined to support SSR messages. The message sub-type is prefixed with “IM” to indicate the IGS SSR relevant message types.

All messages may be split over several messages using the SSR Multiple Message Indicator. It increases the number of e.g. satellites to be transmitted, but it also enables the receiver to begin immediately processing of data after decoding the first message of a multiple message type.

IGM Type	IGM Type Name	No. of Bytes	Notes
IGM01	SSR Orbit Correction	$9.875+16.875*N_S$	N_S = No. of Satellites
IGM02	SSR Clock Correction	$9.75+9.5*N_S$	N_S = No. of Satellites
IGM03	SSR Combined Orbit and Clock Correction	$9.875+25.625*N_S$	N_S = No. of Satellites
IGM04	SSR High Rate Clock Correction	$9.75+3.5*N_S$	N_S = No. of Satellites
IGM05	SSR Code Bias	$9.75+1.375*N_S$ $+2.375*\sum_{i=1}^{N_S} N_{CBi}$	N_S = No. of Satellites N_{CB} = No. of Code Biases per individual Satellite index i indicates N_{CB} for every individual Satellite
IGM06	SSR Phase Bias	$10.0+3.5\ N_S$ $+4.0*\sum_{i=1}^{N_S} N_{PBi}$	N_S = No. of Satellites, N_{PB} = No. of Phase Biases per individual Satellite index i indicates N_{PB} for every individual Satellite
IGM07	SSR URA	$9.75+1.5*N_S$	N_S = No. of Satellites

Table 4 : IGS Generic SSR Message (IGM) Types

Table 5 is an overview of all IGS SSR Sub-Type Message.

IGM Type	GNSS	IGM Type Name	Sub-Type Messages	Notes
			IM000– IM020	Reserved
IGM01	GPS	SSR Orbit Correction	IM021	
IGM02	GPS	SSR Clock Correction	IM022	
IGM03	GPS	SSR Combined Orbit and Clock Correction	IM023	
IGM04	GPS	SSR High Rate Clock Correction	IM024	
IGM05	GPS	SSR Code Bias	IM025	
IGM06	GPS	SSR Phase Bias	IM026	
IGM07	GPS	SSR URA	IM027	
			IM028 – IM040	Reserved for GPS
IGM01	GLONASS	SSR Orbit Correction	IM041	
IGM02	GLONASS	SSR Clock Correction	IM042	

IGM Type	GNSS	IGM Type Name	Sub-Type Messages	Notes
IGM03	GLONASS	SSR Combined Orbit and Clock Correction	IM043	
IGM04	GLONASS	SSR High Rate Clock Correction	IM044	
IGM05	GLONASS	SSR Code Bias	IM045	
IGM06	GLONASS	SSR Phase Bias	IM046	
IGM07	GLONASS	SSR URA	IM047	
			IM048 – IM060	Reserved for GLONASS
IGM01	Galileo	SSR Orbit Correction	IM061	
IGM02	Galileo	SSR Clock Correction	IM062	
IGM03	Galileo	SSR Combined Orbit and Clock Correction	IM063	
IGM04	Galileo	SSR High Rate Clock Correction	IM064	
IGM05	Galileo	SSR Code Bias	IM065	
IGM06	Galileo	SSR Phase Bias	IM066	
IGM07	Galileo	SSR URA	IM067	
			IM068 – IM080	Reserved for Galileo
IGM01	QZSS	SSR Orbit Correction	IM081	
IGM02	QZSS	SSR Clock Correction	IM082	
IGM03	QZSS	SSR Combined Orbit and Clock Correction	IM083	
IGM04	QZSS	SSR High Rate Clock Correction	IM084	
IGM05	QZSS	SSR Code Bias	IM085	
IGM06	QZSS	SSR Phase Bias	IM086	
IGM07	QZSS	SSR URA	IM087	
			IM088 – IM100	Reserved for QZSS
IGM01	BDS	SSR Orbit Correction	IM101	
IGM02	BDS	SSR Clock Correction	IM102	
IGM03	BDS	SSR Combined Orbit and Clock Correction	IM103	
IGM04	BDS	SSR High Rate Clock Correction	IM104	

IGM Type	GNSS	IGM Type Name	Sub-Type Messages	Notes
IGM05	BDS	SSR Code Bias	IM105	
IGM06	BDS	SSR Phase Bias	IM106	
IGM07	BDS	SSR URA	IM107	
			IM108 – IM120	Reserved for BDS
IGM01	SBAS	SSR Orbit Correction	IM121	
IGM02	SBAS	SSR Clock Correction	IM122	
IGM03	SBAS	SSR Combined Orbit and Clock Correction	IM123	
IGM04	SBAS	SSR High Rate Clock Correction	IM124	
IGM05	SBAS	SSR Code Bias	IM125	
IGM06	SBAS	SSR Phase Bias	IM126	
IGM07	SBAS	SSR URA	IM127	
			IM128 – IM140	Reserved for SBAS
			IM141 – IM160	Reserved for NavIC/IRNSS
			IM161 – IM200	Reserved
-	GNSS	SSR Ionosphere VTEC Spherical Harmonics	IM201	
			IM202 – IM254	Reserved

Table 5 : Overview of IGS SSR 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
IM201	SSR Ionosphere VTEC Spherical Harmonics	$10.375+2*N_{IL}+2*N_{HC}$	N_{IL} = No. of ionospheric layers N_{HC} = No. of Harmonic Coefficients (total over all ionospheric layers)

Table 6: Overview of general IGS SSR Sub-Type Messages (IM)

7. DATA FIELDS

7.1 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	IGM/IM Version	0 – 7	1	unit3	The IGM/IM Version is valid for an individual sub-type messages: 0 – experimental 1 – 6 Version 7 – reserved for extension of version range
IDF002	IGS Message Number	0 – 254	1	uint8	IGS RTCM3 Sub-Type Message Number 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: 0 – 1 s 1 – 2 s 2 – 5 s 3 – 10 s 4 – 15 s 5 – 30 s 6 – 60 s 7 – 120 s 8 – 240 s 9 – 300 s 10 – 600 s 11 – 900 s

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					12 – 1800 s 13 – 3600 s 14 – 7200 s 15 – 10800 s 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 IGS Message Number and SSR Epoch Time: 0 – last message of a sequence 1 – multiple message transmitted
IDF006	Global/Regional CRS Indicator	0 – 1	N/A	bit(1)	Orbit corrections refer to CRS: 0 – ITRF 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”. 0 to 255 - reserved for experimental services 256 to 65535 - unique SSR Provider ID
IDF009	SSR Solution ID	0 – 15	1	uint4	SSR Solution ID indicates different SSR services of one SSR provider
IDF010	No. of Satellites	0 – 63	1	uint6	Number of satellites
IDF011	GNSS Satellite ID	0 – 63	1	uint6	Satellite ID is specific for a GNSS. Refer to the following details.

IDF #	**IDF Name**	**IDF Range**	**IDF Resolution**	**Data Type**	**Data Field Notes**
	GNSS Satellite ID for GPS				GPS Satellite ID: 1=1 … 63=63 0=64
	GNSS Satellite ID for GLONASS				GLONASS Satellite ID: 1=1 … 63=63 0=64
	GNSS Satellite ID for Galileo				Galileo Satellite ID: 1=1 … 36=36 >36 Reserved.
	GNSS Satellite ID for QZSS				QZSS Satellite ID: 1=193 2=194 … 10=202 >10 Reserved.
	GNSS Satellite ID for BDS				BDS Satellite ID: 1=1 … 63=63 0=64
	GNSS Satellite ID for SBAS				SBAS Satellite ID: 1=120 2=121 … 39=158 >39 Reserved.
IDF012	GNSS IOD	0 – 255	N/A	bit(8)	GNSS IOD is specific for a GNSS. Refer to the following details
	GNSS IOD for GPS				GPS IOD: Issue of Data (IOD) GPS broadcast Satellite Ephemeris data
	GNSS IOD for GLONASS				GLONASS IOD: Issue of Data (IOD) of GLONASS broadcast Satellite Ephemeris data If bit 7 is 0 (bit 7 is MSb):

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					Bits 0-6 represent the 7 bits of the GLONASS tb (DF110)
	GNSS IOD for Galileo				Galileo IOD: Issue of Data (IOD) Galileo I/NAV broadcast Satellite Ephemeris data, which uses the Galileo IODnav (DF290) 8 LSbs of IODnav
	GNSS IOD for QZSS				QZSS IOD: Issue of Data (IOD) QZSS broadcast Satellite Ephemeris data
	GNSS IOD for BDS				BDS IOD: Issue of Data (IOD) of BDS broadcast Satellite Ephemeris data, which uses the BDS toe (DF505) IOD=mod(toe/720,240)
	GNSS IOD for SBAS				SBAS Satellite ID: Issue of Data (IOD) for SBAS, which is IODN
IDF013	Delta Orbit Radial	±209.7151 m	0.1 mm	int22	Radial orbit correction for broadcast ephemeris. The reference time t0 is SSR Epoch Time (IDF003) plus ½ SSR Update Interval. The reference time t0 for SSR Update Interval "0" is SSR Epoch Time.
IDF014	Delta Orbit Along-Track	±209.7148 m	0.4 mm	int20	Along-Track orbit correction for broadcast ephemeris. See note on reference time t0 of IDF013.
IDF015	Delta Orbit Cross-Track	±209.7148 m	0.4 mm	int20	Cross-Track orbit correction for broadcast ephemeris. See note on reference time t0 of IDF013.
IDF016	Dot Orbit Delta Radial	±1.048575 m/s	0.001 mm/s	int21	Velocity of Radial orbit correction for broadcast ephemeris. See note on reference time t0 of IDF013.
IDF017	Dot Orbit Delta Along-Track	±1.048572 m/s	0.004 mm/s	int19	Velocity of Along-Track orbit correction for broadcast ephemeris.

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					See note on reference time t0 of IDF013.
IDF018	Dot Orbit Delta Cross-Track	±1.048572 m/s	0.004 mm/s	int19	Velocity of Cross-Track orbit correction for broadcast ephemeris. See note on reference time t0 of IDF013.
IDF019	Delta Clock C0	±209.7151 m	0.1 mm	int22	C0 polynomial coefficient for correction of broadcast satellite clock. The reference time t0 is SSR Epoch Time (IDF003) plus ½ SSR Update Interval. The reference time t0 for SSR Update Interval "0" is SSR Epoch Time.
IDF020	Delta Clock C1	±1.048575 m/s	0.001 mm/s	int21	C1 polynomial coefficient for correction of broadcast satellite clock. See note on reference time t0 of IDF019.
IDF021	Delta Clock C2	±1.34217726 m/s2	0.00002 mm/s2	int27	C2 polynomial coefficient for correction of broadcast satellite clock. See note on reference time t0 of IDF019.
IDF022	High Rate Clock Correction	±209.7151 m	0.1 mm	int22	High Rate Clock correction to be added to the polynomial clock correction (see IDF019, IDF020, IDF021)
IDF023	No. of Biases Processed	0 – 31	1	uint5	Number of Code or Phase Biases for one individual satellite
IDF024	GNSS Signal and Tracking Mode Identifier	0 – 31	1	uint5	Signal and Tracking Mode Identifier are specific for a GNSS. Refer to the following details.
	GPS Signal and Tracking Mode Identifier				Indicator to specify the GPS signal and tracking mode: 0 – L1 C/A (1C) 1 – L1 P (AS off) (1P) 2 – L1 Z-tracking and similar (AS on) (1W) 3 – L1C (D) (1S) 4 – L1C (P) (1L) 5 – L2 C/A (2C) 6 – L2 L1(C/A)+(P2-P1)

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					(semi-codeless) (2D) 7 – L2 L2C (M) (2S) 8 – L2 L2C (L) (2L) 9 – Reserved 10 – L2 P (AS off) (2P) 11 – L2 Z-tracking and similar (AS on) (2W) 12 – Reserved 13 – Reserved 14 – L5 I (5I) 15 – L5 Q (5Q) >15 Reserved.
	GLONASS Signal and Tracking Mode Identifier				Indicator to specify the GLONASS signal and tracking mode: 0 – G1 C/A (1C) 1 – G1 P (1P) 2 – G2 C/A (GLONASS M) (2C) 3 – G2 P (2P) 4 – G1a L1OCd (4A) 5 – G1a L1OCp (4B) 6 – G2a L2CSI (6A) 7 – G2a L2OCp (6B) 8 – G3 I (3I) 9 – G3 Q (3Q) >10 Reserved
	GNSS Signal and Tracking Mode Identifier for Galileo				Indicator to specify the Galileo signal and tracking mode: 0 – E1 A PRS (1A) 1 – E1 B I/NAV OS/CS/SoL (1B) 2 – E1 C no data (1C) 3 – Reserved 4 – Reserved 5 – E5a I F/NAV OS (5I) 6 – E5a Q no data (5Q) 7 – Reserved 8 – E5b I I/NAV OS/CS/SoL (7I) 9 – E5b Q no data (7Q) 10 – Reserved 11 – Reserved 12 – Reserved 13 – Reserved 14 – E6 A PRS (6A) 15 – E6 B C/NAV CS (6B) 16 – E6 C no data (6C)

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					17 – Reserved 18 – Reserved >18 Reserved.
	GNSS Signal and Tracking Mode Identifier for QZSS				Indicator to specify the QZSS signal and tracking: 0 – L1 C/A (1C) 1 – L1 L1C (D) (1S) 2 – L1 L1C (P) (1L) 3 – L2 L2C (M) (2S) 4 – L2 L2C (L) (2L) 5 – Reserved 6 – L5 I (5I) 7 – L5 Q (5Q) 8 – Reserved 9 – L6 L6D (6S) 10 – L6 L6P (6L) 11 – Reserved 12 – Reserved 13 – Reserved 14 – Reserved 15 – Reserved 16 – Reserved 17 – L6 L6E (6E) 18 – Reserved >18 Reserved.
	GNSS Signal and Tracking Mode Identifier for BDS				Indicator to specify the BDS signal and tracking: 0 – B1-2 I (2I) 1 – B1-2 Q (2Q) 2 – Reserved 3 – B3 I (6I) 4 – B3 Q (6Q) 5 – Reserved 6 – B2b I (7I) 7 – B2b Q (7Q) 8 – Reserved 9 – B1 Data (1D) 10 – B1 Pilot (1P) 11 – Reserved 12 – B2a Data (5D) 13 – B2a Pilot (5P) 14 – Reserved 15 – B1 B1A (1A) 16 – Reserved 17 – Reserved

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					18 – B3 B3A (6A) >19 Reserved.
	GNSS Signal and Tracking Mode Identifier for SBAS				Indicator to specify the SBAS signal and tracking mode: 0 – L1 C/A (1C) 1 – L5 I (5I) 2 – L5 Q (5Q) 3 – Reserved >3 Reserved.
IDF025	Code Bias	±81.91 m	0.01 m	int14	Code Bias for specified GNSS signal
IDF026	Yaw Angle	0 – (2-1/256) semi-circles	1/256 semi-circles	uint9	Yaw angle used for computation of phase wind-up correction. The Yaw angle is defined as the rotation angle around the satellites Z-axis which is pointing towards the center of the earth. The reference direction is the yaw origin, a unit vector to form an orthogonal basis for the orbit plane and is in the general direction of the satellite velocity vector.
IDF027	Yaw Rate	± (127/8192) semi-circles / second (approx. +/- 2.79 degrees/second)	1/8192 semi-circles / second	int8	Yaw rate – rate of Yaw Angle (IDF026)
IDF028	Phase Bias	± 52.4287 m	0. 0001 m	int20	Phase Bias for specified GNSS Signal. In case of an overflow (phase bias value exceeds the data field range), the phase bias shall be re-initialized to +/- 0.5 cycles of the respective wavelength and the signal discontinuity counter (IDF031) shall be incremented.
IDF029	Signal Integer Indicator	0 – 1	-	bit(1)	Indicator for integer property. 0 – non-integer 1 – signal has integer property
IDF030	Signals Wide-Lane Integer Indicator			bit(2)	Indicator for up to three groups of Wide-Lane(s) integer property.

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					00 – No wide-lane with integer property for this signal or satellite Signals Integer Indicator (IDF029) is already set to 1 10 – signal belongs to group one of wide-lanes with integer property 01 – signal belongs to group two of wide-lanes with integer property 11 – signal belongs to group three of wide-lanes with integer property If the wide-lane of a signal combination has integer property, the corresponding signals shall be grouped into group one and the Signals Wide-Lane Integer Indicator (this IDF) shall be set accordingly for both signals. If the wide-lanes of further signals in combination with a signal of group one have integer properties, the additional signal shall be grouped into the same group and the Signal Wide-Lane Integer Indicator set accordingly. If the wide-lane of further signals, which are not part of previous groups, have integer properties, the signals shall be grouped into the next group and the Signal Wide-Lane Integer Indicator set accordingly. If the wide-lane of a signal combination of any signal in one group with another signal in another group has integer property both groups shall be joined into the smaller group and the other group shall be undefined.
IDF031	Signal Discontinuity Counter	0 – 15	1	uint4	Signal phase discontinuity counter. Increased for every discontinuity in phase. Roll-over from 15 to 0.
IDF032	Dispersive Bias Consistency Indicator	0 – 1	1	bit(1)	Indicator for the dispersive phase biases property.

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					0 – phase biases valid for non-dispersive signal only, i.e. phase biases cannot be used as correction to derive bias-free dispersive observations. 1 – phase biases maintain consistency between non-dispersive and all original dispersive phase signals, i.e. phase biases can be used as corrections to derive bias-free dispersive observations
IDF033	MW Consistency Indicator	0 – 1	1	bit(1)	Consistency indicator for Melbourne-Wübbena (MW) linear combinations. 0 – code and phase biases are independently derived, i.e. they cannot be used as corrections to derive bias-free MW linear combinations 1 – consistency between code and phase biases is maintained for the MW combinations, i.e. code and phase biases can be used as corrections to derive bias-free MW combinations
IDF034	SSR URA	bits 5 – 3: 0 – 7 bits 2 – 0: 0 – 7		bit(6)	SSR User Range Accuracy (URA) (1 sigma) for a range correction computed from complete SSR set as disseminated by SSR messages. The URA is represented by a combination of URA_CLASS and URA_VALUE. The 3 MSb define the URA_CLASS with a range of 0 – 7. The 3 LSb define the URA_VALUE with a range of 0 – 7. The URA is computed by: $\mathrm{URA}\ [\mathrm{mm}] \leq 3^{\mathrm{URA\_CLASS}}\left(1+\frac{\mathrm{URA\_VALUE}}{4}\right) - 1\ [\mathrm{mm}]$

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
					Special cases are: 000 000 – URA undefined/ unknown, SSR corrections for the corresponding satellite may not be reliable 111 111 – URA > 5466.5 mm
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.

IDF #	IDF Name	IDF Range	IDF Resolution	Data Type	Data Field Notes
IDF041	VTEC Quality Indicator	0 – 25.55 TECU	0.05 TECU	uint9	VTEC quality indicator for vertical ionospheric effect not described by the spherical harmonic expansions. 0 – unknown 25.55 – indictor exceeds 25.54 TECU

Table 7 : IGS SSR data fields

7.2 Additional GNSS Specific Notes

7.2.1 GPS

The relativity correction has to be applied for GPS according to the GPS ICD to compute $t_{broadcast}$. The relativistic correction term $\Delta \boldsymbol{t}_T$ to be used is based on the orbital elements.

Note: The GPS ICD contains two different formulas for the relativistic correction. A second formula is based on ECEF satellite broadcast position and velocity vector. The ICD states identity between them, but there is actually a numerical difference.

7.2.2 GLONASS

The computation of satellite positions and satellite clock offsets from broadcast data must be consistent. The GLONASS ICD refers to two different algorithms. For SSR, the GLONASS broadcast ephemeris computation "Simplify of algorithm for re-calculation of ephemeris to current time" must be used.

The relativistic effects are already accounted for in the broadcast clock parameters for GLONASS.

Note: The numerical integration of satellite coordinates from broadcast ephemeris should be performed with sufficient accuracy. For instance, the Runge-Kutta method of 4th order with the step of numerical integration that does not exceed 30 seconds can be used to obtain a precision of 0.1 mm.

7.2.3 Galileo

According to the Galileo OS SIS ICD, Issue 1.1, September 2010, there are two different clock representations for Galileo satellite clock corrections, namely the F/NAV and the I/NAV clock. The clocks are transmitted for different services and signals. F/NAV is for Dual-frequency (E1, E5a) or Single-frequency E5a services. I/NAV is available for Dual-Frequency (E1, E5b), Single-frequency E5b and Single-frequency E1. The clocks will be derived from dual frequency ionosphere free linear combinations of observables on E1/E5A or E1/E5b respectively.

For both, F/NAV and I/NAV, clock polynomial coefficients and a reference time are provided by Galileo. However, there is no information on consistency of both clocks in conjunction with group delay parameters transmitted.

Clock corrections in RTCM-SSR are related to a broadcast reference clock. The I/NAV clock has been chosen as the reference clock for RTCM Galileo SSR correction.

The relativity correction has to be applied for Galileo according to Galileo ICD to compute $t_{broadcast}$. The relativistic correction term $\Delta \boldsymbol{t}_T$ to be used is based on the orbital elements.

7.2.4 QZSS

The relativity correction has to be applied for QZSS according to QZSS ICD to compute $t_{broadcast}$. The relativistic correction term $\Delta \boldsymbol{t}_T$ to be used is based on the orbital elements.

7.2.5 BDS

The relativity correction has to be applied for BDS according to BDS ICD to compute $t_{broadcast}$. The relativistic correction term $\Delta \boldsymbol{t}_T$ to be used is based on the orbital elements.

7.2.6 SBAS

The Satellite-based Augmentation System (SBAS) broadcast ephemeris is identified by the Issue of Data Navigation (IODN). The IODN is defined as the first 8 bits after the message type 9, called IODN in RTCA DO229, Annex A and Annex B and called spare in Annex C (RINEX).

Although, the IODN is called spare in the RTCA DO229, it is used for the IGS SSR correction messages as SBAS broadcast ephemeris indicate support and increasing count of the IODN.

There is no relativity correction for SBAS. Any relativity effects are removed by the control center of the SBAS signal according to RTCA DO229.

8. SSR CORRECTION MESSAGES

8.1 GNSS SSR Orbit and Clock Corrections

The GNSS satellite orbit correction message content is defined in Table 8 and Table 9, consisting of a header and satellite specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	

Data Field	IDF/DF Number	Data Type	No. of Bits	Notes
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
Global/Regional CRS Indicator	IDF006	bit(1)	1	
No. of Satellites	IDF010	uint6	6	
TOTAL			***79***	

Table 8 : Header Part of the GNSS SSR Orbit Correction Message IGM01

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
GNSS IOD	IDF012	bit(8)	8	
Delta Orbit Radial	IDF013	int22	22	
Delta Orbit Along-Track	IDF014	int20	20	
Delta Orbit Cross-Track	IDF016	int20	20	
Dot Orbit Delta Radial	IDF015	int21	21	
Dot Orbit Delta Along-Track	IDF017	int19	19	
Dot Orbit Delta Cross-Track	IDF018	int19	19	
TOTAL			***135***	

Table 9 : Satellite Specific Part of the GNSS SSR Orbit Correction Message IGM01

The GNSS satellite clock correction message content is defined in Table 10 and Table 11, consisting of a header and satellite specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
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/DF Number	Data Type	No. of Bits	Notes
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
No. of Satellites	IDF010	uint6	6	
TOTAL			***78***	

Table 10 : Header Part of the GNSS SSR Clock Correction Message IGM02

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
Delta Clock C0	IDF019	int22	22	
Delta Clock C1	IDF020	int21	21	
Delta Clock C2	IDF021	int27	27	
TOTAL			***76***	

Table 11 : Satellite Specific Part of the of the GNSS SSR Clock Correction Message IGM02

The GNSS combined satellite orbit and clock correction message content is defined in Table 12 and Table 13, consisting of a header and satellite specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
Global/Regional CRS Indicator	IDF006	bit(1)	1	

Data Field	IDF/DF Number	Data Type	No. of Bits	Notes
No. of Satellites	IDF010	uint6	6	
TOTAL			***79***	

Table 12 : Header Part of the GNSS SSR Combined Orbit and Clock Correction Message IGM03

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
GNSS IOD	IDF012	bit(8)	8	
Delta Orbit Radial	IDF013	int22	22	
Delta Orbit Along-Track	IDF014	int20	20	
Delta Orbit Cross-Track	IDF015	int20	20	
Dot Orbit Delta Radial	IDF016	int21	21	
Dot Orbit Delta Along-Track	IDF017	int19	19	
Dot Orbit Delta Cross-Track	IDF018	int19	19	
Delta Clock C0	IDF019	int22	22	
Delta Clock C1	IDF020	int21	21	
Delta Clock C2	IDF021	int27	27	
TOTAL			***205***	

Table 13 : Satellite Specific Part of the GNSS SSR Combined Orbit and Clock Correction Message IGM03

The GNSS satellite high rate clock correction message content is defined in Table 14 and Table 15, consisting of a header and satellite specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	

Data Field	IDF/DF Number	Data Type	No. of Bits	Notes
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
No. of Satellites	IDF010	uint6	6	
TOTAL			***78***	

Table 14 : Header Part of the GNSS SSR High Rate Clock Correction Message IGM04

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
High Rate Clock Correction	IDF022	int22	22	
TOTAL			***28***	

Table 15 : Satellite Specific Part of the GNSS SSR High Rate Clock Correction Message IGM04

8.2 GNSS SSR Bias Corrections

The GNSS satellite code bias message content is defined in Table 16, Table 17 and Table 18, consisting of a header, satellite and bias specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	

Data Field	IDF/DF Number	Data Type	No. of Bits	Notes
SSR Solution ID	IDF009	uint4	4	
No. of Satellites	IDF010	uint6	6	(No. of Satellites) * (SV Block) will immediately follow this IDF.
TOTAL			***78***	

Table 16 : Header Part of the GNSS SSR Code Bias Message IGM05

Each SV Block consists of a satellite specific part immediately followed by a code specific part per processed code bias for the corresponding satellite.

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
No. of Biases Processed	IDF023	uint5	5	The Code Specific Parts for all processed Code Biases are directly following the Satellite Specific Part of the corresponding satellite. (No. of Code Biases Processed) * (Code Specific Part) will immediately follow this IDF.
TOTAL			***11***	

Table 17 : Satellite Specific Part of the of the GNSS SSR Code Bias Message IGM05

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Signal and Tracking Mode Identifier	IDF024	uint5	5	
Code Bias	IDF025	int14	14	
TOTAL			***19***	

Table 18 : Code Specific Part of the of the GNSS SSR Code Bias Message IGM05

The GNSS satellite phase bias correction message content is defined in Table 19, Table 20 and Table 21, consisting of a header, satellite and bias specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
Dispersive Bias Consistency Indicator	IDF032	bit(1)	1	
MW Consistency Indicator	IDF033	bit(1)	1	
No. of Satellites	IDF010	uint6	6	
TOTAL			***80***	

Table 19 : Header Part of the GNSS SSR Phase Bias Message IGM06

Each SV Block consists of a satellite specific part immediately followed by a phase specific part per processed phase bias for the corresponding satellite.

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
No. of Biases Processed	IDF023	uint5	5	
Yaw Angle	IDF026	uint9	9	
Yaw Rate	IDF027	int8	8	
TOTAL			***28***	

Table 20 : Satellite Specific Part of the of the GNSS SSR Phase Bias Message IGM06

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Signal and Tracking Mode Identifier	IDF024	uint5	5	
Signal Integer Indicator	IDF029	bit(1)	1	
Signals Wide-Lane Integer Indicator	IDF030	bit(2)	2	
Signal Discontinuity Counter	IDF031	uint4	4	
Phase Bias	IDF028	int20	20	
TOTAL			***32***	

Table 21 : Phase Specific Part of the of the GNSS SSR Phase Bias Message IGM06

8.3 GNSS SSR URA Messages

The GNSS satellite clock correction message content is defined in Table 22 and Table 23, consisting of a header and satellite specific part.

Data Field	IDF/DF Number	Data Type	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	GNSS specific IM Number
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
IOD SSR	IDF007	uint4	4	
SSR Provider ID	IDF008	uint16	16	
SSR Solution ID	IDF009	uint4	4	
No. of Satellites	IDF010	uint6	6	
TOTAL			***78***	

Table 22 : Header Part of the GNSS SSR URA Message IGM07

Data Field	IDF Number	Data Type	No. of Bits	Notes
GNSS Satellite ID	IDF011	uint6	6	
SSR URA	IDF034	bit(6)	6	
TOTAL			***12***	

Table 23 : Satellite Specific Part of the GNSS SSR URA Message IGM07

8.4 SSR IONOSPHERE CORRECTION MESSAGE

8.4.1 SSR Ionosphere VTEC Spherical Harmonics Message

Table 24 through Table 27 provide the contents of the SSR Ionosphere VTEC Spherical Harmonics message. The message consists of a header part (Table 24) followed by the model for every individual ionospheric layer (Table 25 - Table 27).

Data Field	IDF/DF 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	201
SSR Epoch Time 1s	IDF003	uint20	20	
SSR Update Interval	IDF004	bit(4)	4	
SSR Multiple Message Indicator	IDF005	bit(1)	1	
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 24 : Header Part of the SSR Ionosphere VTEC Spherical Harmonics IM201

Every ionospheric layer model has an Ionosphere Layer Header (Table 25) and two subsequent model parts with Cosine Coefficients (Table 26) and Sine Coefficients (Table 27).

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 25 : Header Part for an Ionospheric Layer IM201

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 26 : Model Part of the SSR Ionosphere VTEC Spherical Harmonic Cosine Coefficients IM201

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 27 : Model Part of the SSR Ionosphere VTEC Spherical Harmonic Sine Coefficients IM201

The number of harmonic coefficients for one layer is defined by the corresponding degree N and order M. The overall number of cosine and sine coefficients for each layer is computed according to:

$$\text{No. of Coefficients } = (N+1)(N+1) - (N-M)(N-M+1)$$

The sequence of the harmonic coefficients in the message is first the cosine terms C followed by the sine terms S within each group:

C_{nm} (m=0,M, n=m,N)
S_{nm} (m=1,M, n=m,N)

I.e. with degree $N = 3$, order $M = 2$ the sequence of the harmonic coefficients within one layer with corresponding index n, m reads

C_{00}, C_{10}, C_{20}, C_{30},	(m=0, n=0…3)
C_{11}, C_{21}, C_{31},	(m=1, n=1…3)
C_{22}, C_{32},	(m=2, n=2…3)
S_{11}, S_{21}, S_{31},	(m=1, n=1…3)
S_{22}, S_{32}	(m=2, n=2…3)

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