GLOBAL NAVIGATION SATELLITE SYSTEM

GLONASS

Open Service Performance Standard (OS PS)

APPENDIX D
GLONASS CDMA Performance Parameters

Revision 1.0

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D.1 General Statements

GLONASS Space Vehicle Subsystem timescale is formed now in dedicated GLONASS frequency and time provision contour and is implemented in a form of conditional continuous timescale basing on Central Synchronizer timescale. GLONASS Space Vehicle Subsystem timescale is formed basing on Central Synchronizer data measurements and its timescale offset with Time and Frequency national standard timescale.

The navigation message of each GLONASS CDMA signal contains polynomial model parameters allowing navigation equipment to calculate the offset between time of the signal and GLONASS time. Consequently GLONASS CDMA signals do not use basic signal concept – time of each signal is independent.

Ephemeris data transmitted in GLONASS CDMA signals, compared to similar data in GLONASS FDMA signals, is tied to SV' center of mass. Ephemeris data numerical values tied to the same moment of time are the similar for L1OC and L3OC signals. Antenna phase center coordinates calculations are conducted in user navigation equipment using measurements in PZ-90 tied to the certain antenna phase center. Coordinates of antenna phase centers for that signal in SV-fixed reference system are transmitted in strings type 10-12 of navigation message for those calculations.

D.2 CSA SIS URE accuracy affecting factors

As known, during orbit and clock data lifecycle from generation to using by user the major affecting factors for CSA SIS URE accuracy regardless the propagation environment and receiver induced biases are:

- Accuracy of orbit and clock data generation (GLONASS Command and Control Subsystem contribution);
- Accuracy of orbit and clock data forecast (SV AFS stability and orbit and clock data broadcast and multiplication methods contribution);
- Accuracy of orbit and clock data representation in FDMA and CDMA signals (navigation message field parameters contribution);
- Accuracy of intersignal biases in single and dual frequency measurements.

D.2.1 Accuracy of FDMA and CDMA signals orbit and clock data generation

Accuracy of FDMA and CDMA signals orbit and clock data generation depends on hardware and software, measurements processing algorithms and measuring means structure.

Ephemerides for CDMA signals are formed by the same processing centers as for FDMA signals.

Frequency and time provision contour forms frequency and time data for CDMA signals in parallel with FDMA contour. With this, the use of generic processes, processing algorithms and hardware and software allows expecting frequency and time provision performance at least on the same level of accuracy and reliability. Intra-frequency delays absence and use of technology with independent onboard timescales of all signals provides accuracy improvement.

D.2.2 Accuracy of orbit and clock data forecast

Accuracy of clock data forecast is determined most significantly by SVs AFS stability. Despite installation of AFS with increased stability ($1\text{-}5\text{x}10^{-14}$) to advanced SVs, accuracy of orbit and clock data forecast for CDMA signals will not at least be worse than the accuracy for the FDMA signals, transmitted by the same SV. Moreover, taking into account that first L3 CDMA signals are already transmitting from current «Glonass-M» SV modification, for the time being it should be considered that the accuracy of frequency and clock data forecast for CDMA signals generally corresponds to the accuracy of frequency and clock data forecast for FDMA signals. In future, with new SVs modifications being launched, FDMA and CDMA orbit and clock data forecast accuracy will be improved simultaneously.

D.2.3 Accuracy of orbit and clock data representation in FDMA and CDMA signals

Table D.1 shows orbit and clock data parameters, which are transmitted in GLONASS FDMA signals navigation message. Table D.2 orbit and clock data parameters, which are transmitted in GLONASS CDMA signals navigation message.

Table D.1 – Orbit and clock data fields parameters for GLONASS FDMA signals

Field	Number of bits	Least significant bit	Value range	Unit
$\tau_n(t_b)$	22	2^{-30}	$\pm 2^{-9}$	s
$\gamma_n(t_b)$	11	2^{-40}	$\pm 2^{-30}$	-
$x^j(t_b), y^j(t_b), z^j(t_b)$	27	2^{-11}	$\pm 2{,}7*10^4$	km
$\dot{x}^j(t_b), \dot{y}^j(t_b), \dot{z}^j(t_b)$	24	2^{-20}	$\pm 4{,}3$	km/s
$\ddot{x}^j(t_b), \ddot{y}^j(t_b), \ddot{z}^j(t_b)$	5	2^{-30}	$\pm 6{,}2*10^{-9}$	km/s^2

Table D.2 – Orbit and clock data fields parameters for GLONASS CDMA signals

Field	Number of bits	Least significant bit	Value range	Unit
$\tau^j(t_b)$	32	2^{-38}	$\pm 7{,}8*10^{-3}$	s
$\gamma^j(t_b)$	19	2^{-48}	$\pm 0{,}9*10^{-9}$	-
$\beta^j(t_b)$	15	2^{-57}	$\pm 1{,}1*10^{-13}$	s^{-1}
$\tau_c(t_b)$	40	2^{-31}	± 256	s
$\dot{\tau}_c(t_b)$	13	2^{-49}	$\pm 0{,}7*10^{-11}$	-
$x^j(t_b), y^j(t_b), z^j(t_b)$	40	2^{-20}	$\pm 5{,}2*10^5$	km
$\dot{x}^j(t_b), \dot{y}^j(t_b), \dot{z}^j(t_b)$	35	2^{-30}	± 16	km/s
$\ddot{x}^j(t_b), \ddot{y}^j(t_b), \ddot{z}^j(t_b)$	15	2^{-39}	$\pm 2{,}9*10^{-8}$	km/s^2
$\Delta x^j_{pc}, \Delta y^j_{pc}, \Delta z^j_{pc}$	13	2^{-10}	± 4	m

where:

$\tau^j(t_b)$ – a correction to onboard timescale (L1OCd, L3OCd) for number j SV (transmitting current navigation message) for transformation to GLONASS time at the instant t_b;
$\gamma^j(t_b)$ – a relative deviation of carrier frequency $f^j(t_b)$ for number j SV from the nominal carrier frequency f_c at the instant t_b;

$\beta^j(t_b)$ – a half rate of relative deviation ($\gamma^j(t_b)$) of carrier frequency $f^j(t_b)$ of nominal carrier frequency f_C of number j SV at the instant t_b;

$\tau_c(t_b)$ – a correction for transformation from GLONASS time to MT at the instant t_b;
$\dot{\tau}_c(t_b)$ – a rate of $\tau_c(t_b)$ correction at the instant t_b;
$x^j(t_b)$, $y^j(t_b)$, $z^j(t_b)$ – the coordinates of the center of mass of number j SV (transmitting current navigation message) at the instant t_b in the PZ-90. $x^j(t_b)$, $y^j(t_b)$, $z^j(t_b)$ contain precise ephemerides (coordinates) calculated based on precise dynamic model;

$\dot{x}^j(t_b)$, $\dot{y}^j(t_b)$, $\dot{z}^j(t_b)$ – the velocity vectors of number j SV center of mass at the instant t_b in the PZ-90. $\dot{x}^j(t_b)$, $\dot{y}^j(t_b)$, $\dot{z}^j(t_b)$ contain the coordinated ephemerides (velocities) which are calculated based on precise ephemerides in the manner which allows minimizing on average methodological errors of ephemeris prediction at forecast interval using the simplified dynamic model in navigation equipment;

$\ddot{x}^j(t_b)$, $\ddot{y}^j(t_b)$, $\ddot{z}^j(t_b)$ – vector components of perturbing accelerations of number j SV (transmitting current navigation message) center of mass at the instant t_b in the PZ-90. $\ddot{x}^j(t_b)$, $\ddot{y}^j(t_b)$, $\ddot{z}^j(t_b)$ contain the coordinated ephemerides (accelerations) which were calculated based on precise ephemerides in the manner which allows minimizing on average methodological errors of ephemeris prediction at forecast interval using the simplified dynamic model in navigation equipment;

Δx^j_{pc}, Δy^j_{pc}, Δz^j_{pc} – coordinates of the antenna phase center transmitting L1OC and L3OC signals.

As seen from comparison of D.1 and D.2 Tables, in GLONASS CDMA signals not only the least significant bit of all FDMA parameters is significantly decreased, but also frequency and time corrections forecast polynomial degree is added for forecast accuracy improvement. Moreover, antenna phase center – center of mass offset is transmitted in navigation message. Consideration of this offset allows to compensate one of measurement error components.

The accuracy of orbit and clocks data in FDMA signals is 0.5 m for each axis. The accuracy of frequency and time corrections representation is 0.3 m. The similar situation is with the derivative values of these components. In this regard, CSA SIS Accuracy is 0,25 m due to navigation message digital data representation accuracy. The accuracy of orbit and clocks corrections representation in CDMA signals is significantly improved compared to FDMA signals and is on 1 mm level on 15 min forecast interval at the measurements conduction moment of time.

D.2.4 Accuracy of intersignal biases in single and dual frequency measurements

There is a physical offset between radio signals phases due to hardware biases, with that L1OF-L3OC and L1OC-L3OC offsets are different. Hardware biases values definition in corresponding sub bands is conducted by onboard navigation signal generator manufacturer. After that they are used in navigation message creation.

Due to many factors, connected with signal propagation from output jacks of power amplifiers of onboard navigation signal generator to signal emission phase centers, there is a drift between hardware offsets logbook values and real values. Offset drift is determined by antenna elements parameters degradation (summarizers, splitters, triplexers) as well as by temperature conditions changes of these elements due to «seasonal» SVs sun lighting parameters drift. For the time being for single frequency L1OF user this drift is not calculated.

Implementation of independent onboard timescales of CDMA signals gives the opportunity to include offsets mentioned above to frequency and time corrections. CSA SIS URE Accuracy for L1OF-L3OC combination will be worse compared to L1OC-L3OC. This results from L1OF being the base for FDMA signals. There are ongoing activities to implement the possibility of considering antenna and onboard navigation signal generator offsets for L1OF signal using the method of in-orbit calibration and their further compensation in onboard software the corrections by true offset values or corresponding changes to frequency and time corrections in system documents for GLONASS.

For FDMA signals the offset value between transmitted radio signal (measured in SV’ antenna phase center) and onboard AFS output signal (non-deterministic component’s maximum value) is ±2 ns for «Glonass-M» SV. For new generation SV the value will be similar.

Opposed to FDMA signals ionosphere-free combination for CDMA signals has no unknown error components, thus SIS URE budget component dependent on intersignal biases for single and dual frequency CDMA signal users will be less than this SIS URE component of FDMA signals.

D.3 Range domain accuracy (CSA SIS Accuracy)

Before collecting detailed and full statistical data and conducting its analysis on CDMA signals, it is proposed to use FDMA signals range domain accuracy standards specified in GLONASS SPS for CDMA signals.

Table D.3 – Range domain accuracy (CSA SIS Accuracy) standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
CSA SIS Accuracy Standards					
– **for any healthy SV**	18 m	18 m	18 m	18 m	18 m
– **95% for any healthy SV**	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
– **95% over all healthy SV**	7.8 m	7.8 m	7.8 m	7.8 m	7.8 m
– **95% SIS URRE for any healthy SV**	0.014 m/s	0.014 m/s	0.014 m/s	0.014 m/s	0.014 m/s
– **95% SIS URRAE for any healthy SV**	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2

D.4 Positioning Accuracy (CSA Position) and CSA SIS Availability

Positioning accuracy (CSA Position) and CSA SIS Availability are defined as a function from instantaneous SIS URE and observed constellation geometry. Considering standards being issued for fully deployed constellation, that is identical from the structure point of view for both FDMA and CDMA signals, with similar SIS URE initial values for FDMA and CDMA, CSA Position and CSA SIS Availability will also be the same. Therefore, it is proposed to use the same performance parameters values as for FDMA level.

Table D.4 – Positioning accuracy (CSA Position) standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Positioning Accuracy Standards					
– **95% Global Average:**					
– **Horizontal Error**	5 m	5 m	5 m	5 m	5 m
– **Vertical Error**	9 m	9 m	9 m	9 m	9 m
– **95% Worst Site:**					
– **Horizontal Error**	12 m	12 m	12 m	12 m	12 m
– **Vertical Error**	25 m	25 m	25 m	25 m	25 m

Table D.5 – CSA SIS Availability standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Availability Standards					
− **Average location:**					
− **Horizontal Service Availability**	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)
− **Vertical Service Availability**	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)
− **Worst-case location:**					
− **Horizontal Service Availability**	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)
− **Vertical Service Availability**	90%, (25 m 95% threshold)	90%, (25 m 95% threshold)	90%, (25 m 95% threshold)	90%, (25 m 95% threshold)	90%, (25 m 95% threshold)

D.5 Time Transfer Accuracy

Navigation message contains GLONASS and UTC(SU) timescales offset data. During normal operation the accuracy of that data on transmission interval is so that UTC (UTCOE) of GLONASS and UTC(SU) timescales lies within 40 ns interval with 95% probability, as shown in current version of GLONASS OS PS for FDMA signals.

UTCOE is formed with comparison with the Time and Frequency national standard timescale (p. D-4), is independent from signal parameters and is the same for FDMA and CDMA. As it was shown, SIS URE value will be at minimum no worse than as for FDMA signals. That is the reason of using the same parameters values as for FDMA level.

Table D.6 – Time Transfer Accuracy standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Time Transfer Accuracy Standards	40 ns	40 ns	40 ns	40 ns	40 ns

D.6 Reliability of major service failure and Probability of constellation fault

Reliability parameters as well as P_{sat} and P_{const} are in some or other form the SIS URE value distribution function on long-duration data sample. Due to the extent of onboard software and hardware means in use as well as calculations provided for CDMA signals SIS URE improvement shown in Section D.2, the parameters values used for CDMA signals may coincide with FDMA parameters values level. With that, as well as for FDMA, the key parameters for reliability provision requires continuous monitoring and alerting system activation in case of their non-fulfillment.

Table D.7 – Reliability Standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Reliability Standards:					
− **Global Average**	99.37%	99.37%	99.37%	99.37%	99.37%
− **Worst Site**	99.14%	99.14%	99.14%	99.14%	99.14%

Table D.8 – Reliability of major service failure standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Reliability of major service failure (P_{sat}) Standards	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)

Table D.9 – Probability of constellation fault standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Probability of constellation fault (P_{const}) Standards	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)	$1*10^{-4}$, (70 m threshold)

D.7 Continuity

In GLONASS OS PS the continuity value is determined more conservatively due to the GLONASS orbital constellation replenishment strategy on operational needs, keeping a number of SVs functioning out of active lifecycle period and the results of conducted statistical analysis. The similar conservative approach is justified to be pursued regarding new signals implementation taking into account possible technical maintenance outages. Therefore, the same conservative FDMA values are used for CDMA signals while subsequent improvement being possible after receiving statistical data.

Table D.10 – Continuity standards according to signals combination being used

Signals Combination	**L1OF**	**L1OC**	**L3OC**	**L1OF - L3OC**	**L1OC - L3OC**
Continuity Standards	$2*10^{-3}$	$2*10^{-3}$	$2*10^{-3}$	$2*10^{-3}$	$2*10^{-3}$

D.8 General approach for defining FDMA performance parameters values

At initial stage, before collecting and processing detailed and full statistical data, indicated values of GLONASS CDMA-based services performance parameters values are the same as used for GLONASS FDMA signalsl. This provides sufficient conservative capacity for real values of performance parameters fluctuation and future potential improvement.

In future, with new orbital constellation deployment for all types of services, basing on real-time statistical data evaluation, listed parameters can be refined towards the reduction of the conservative capacity and performance parameters values improvement.