Beidou Timescale Description

Reference document

RD1: BeiDou Satellite Navigation System Signal In Space Interface Control Document, Open Service Signal (Version 2.0), Nov. 2013.

Definition of time system

1.System timescale: BDT (Beidou System Time)

2. Generation of system timescale:
Composite clock based on the clock ensembles of master control station and monitor station

3. Is system timescale steered to a reference UTC timescale?
Yes

a. To which reference timescale: linked to UTC through UTC(NTSC).

b. whole second offset from reference timescale?
Yes,
BDT is a uniform scale and is 33 seconds behind TAI（BDT-TAI=-33s）.
BDT relation to UTC changes corresponding to the addition/subtraction of leap seconds.

c. Maximum offset from reference timescale?
100 nanoseconds (modulo 1s).

4. Corrections to convert from satellite to system timescale?
Yes

a. Type of corrections given: include statement on relativistic corrections
Quadratic coefficients, broadcast as part of the BDS navigation message. The expression for relativistic correction is given in BDS-SIS-ICD-2.0 20131226.

b. Specified accuracy of corrections to system timescale
Accuracy of corrections to system timescale: 2 nanoseconds

c. Location of corrections in broadcast messages
Subframe 1 of BDS navigation message.

d. Equations to correct satellite timescale to system timescale
BDT is modelled through the following polynomial:

$$t = t_{sv} - \Delta t_{sv}$$

Where: t is the BDT (when the signal is sending) in seconds;
t_{sv} is the satellite ranging code phase time (when the signal is sending) in seconds;
Δt_{sv} is the satellite ranging code phase time difference between t_{sv} and BDT

in seconds, expressed as follows:

$$\Delta t_{sv} = a_0 + a_1\left(t - t_{oc}\right) + a_2\left(t - t_{oc}\right)^2 + \Delta t_r$$

Where, t is ignored its precision, t_{sv} can be substituted for it.

Δt_r is relativistic emendation term in seconds, expressed as follows:

$$\Delta t_r = F \cdot e \cdot \sqrt{A} \cdot \sin E_k$$

Where: e is the satellite orbital eccentricity, obtained from satellite ephemeris parameters;

$\sqrt{A}$ is the square root of satellite orbit semi-major axis, obtained from satellite ephemeris parameters;

E_k is the satellite orbit eccentric anomaly, obtained from satellite ephemeris parameters;

$F = -2\mu^{1/2} / C^2$

$\mu = 3.986004418 \times 10^{14} m^3 / s^2$, is the earth's gravitational constant;

$C = 2.99792458 \times 10^8\ m / s$, is the speed of light;

B1I signal user, need to use the following correction:

$$\left(\Delta t_{sv}\right)_{B1I} = \Delta t_{sv} - T_{GD1}$$

T_{GD1} is the correction parameter for frequency B1 user, which is broadcasted in the navigation messages.

B2I signal user, need to use the following correction:

$$\left(\Delta t_{sv}\right)_{B2I} = \Delta t_{sv} - T_{GD2}$$

T_{GD2} is the correction parameter for frequency B2 user, which is broadcasted in the navigation messages.

5. Corrections to convert from system to reference UTC timescale?

Yes

a. Type of correction given

Linear coefficients and leap second terms.

b. Specified accuracy of corrections to reference timescale

5 nanoseconds (95%), the uncertainty of BDT to ground reference timescales.

c. Location of corrections in broadcast message

Subframe 5 of BDS, page 10 (BDS-SIS-ICD-2.0 20131226)

d. Equations to correct system timescale to reference timescale

This parameters reflect the relationship between BDT and UTC,

parameter	bit	Scaling factor	Effective range	unit
A_{0UTC}	32*	2^{-30}	—	s
A_{1UTC}	24*	2^{-50}	—	s/s
Δt_{LS}	8*	1	—	s
WN_{LSF}	8	1	—	week
DN	8	1	6	day
Δt_{LSF}	8*	1	—	s
* is binary complement, most significant bit（MSB）is sign bit（+或-）。				

A_{0UTC}: BDT relative to UTC's clock error;
A_{1UTC}: BDT relative to UTC's clock rate;
Δt_{LS}: BDT relative to UTC's cumulative leap second correction (before new leap second takes effect);
WN_{LSF}: week number (before new leap second takes effect);
DN: day number in a week (before new leap second takes effect);
Δt_{LSF}: BDT relative to UTC's cumulative leap second correction (after new leap second takes effect);
UTC is calculated by BDT:
UTC parameter , WN_{LSF} and DN are broadcasted to user by the system, the error is less than 1 microsecond.
Considering the relationship between the time leap second takes effect and the system current time of user, if it is current, three kinds of transformation relations between BDT and UTC.

1) When WN_{LSF} and DN are not obtained, and the current time of user t_E is before DN+2/3, transformation relation between BDT and UTC:

$$t_{UTC} = (t_E - \Delta t_{UTC})[Modulo 86400], \mathrm{Sec}ond$$

Where:

$$\Delta t_{UTC} = \Delta t_{LS} + A_{0UTC} + A_{1UTC} \times t_E, \mathrm{Sec}ond$$

Where, t_E is BDT which is computed by user, adopted second number in a week.

2) If t_E is between WN_{LSF} and DN+2/3~ DN+5/4, transformation relation between BDT and UTC:

$$t_{UTC} = W[Modulo(86400 + \Delta t_{LSF} - \Delta t_{LS})], \mathrm{Sec}ond$$

Where:

$$W = (t_E - \Delta t_{UTC} - 43200)[Modulo 86400] + 43200, \mathrm{Sec}ond$$

$$\Delta t_{UTC} = \Delta t_{LS} + A_{0UTC} + A_{1UTC} \times t_E, \mathrm{Sec}ond$$

3) When WN_{LSF} and DN are in the past, and t_E is after DN+5/4, transformation relation between BDT and UTC:

$$t_{UTC} = (t_E - \Delta t_{UTC})[Modulo 86400], \text{Second}$$

Where:

$$\Delta t_{UTC} = \Delta t_{LSF} + A_{0UTC} + A_{1UTC} \times t_E, \text{Second}$$

Definitions of parameters in expressions above are the same with 1).

6. Specified stability of system timescale

The stability of BDT is about 2.0E-14 at 1 day interval, 1.0E-14 at 7 days interval.

7. Specified stability of reference timescale

better than 5E-15 per day.

8. Specified stability of satellite clocks

better than 1E-13 per day.

9. Availability of system to GNSS Time offset (BGTO)

The offset of BDT, GPST, GLNT, and GST will be broadcasted by BDS, as a part of navigation message.

a. System for which corrections are given

GPS, GLONASS and Galileo

b. Type of BGTO corrections given

Linear model

c. Stated accuracy of BGTO correction, if available

N/A

d. Location of corrections in broadcast messages

Subframe 5 of D1, page 9 (BDS-SIS-ICD-2.0 20131226)

e. Equations used for BGTO message

The offset parameters of BDT and GPST, as follows:

parameter	bit	Scaling factor	unit
A_{0GPS}	14*	0.1	ns
A_{1GPS}	16*	0.1	ns/s
* is binary complement，most significant bit（MSB）is sign bit（+或-）。			

A_{0GPS}: BDT relative to GPS’s clock error;

A_{1GPS}: BDT relative to GPS’s clock rate;

Conversion expressions for BDT and GPS as follows:

$$t_{GPS} = t_E - \Delta t_{GPS}$$

Where, $\Delta t_{GPS} = A_{0UTC} + A_{1UTC} \times t_E$, t_E is BDT computed by user, adopted second number in a week.

The offset parameters of BDT and GST, BDT and GLNT are familiar with it.

Describe the details of the system, i.e. locations of system and reference timescale clocks, generation of timescales, and other details.

BDT is generated and maintained by the master control station of BDS. BDT is calculated based on the hydrogen clocks in master control station and monitor stations. The master control station is located in Beijing and the monitor stations are distributed in China. The master clock of BDT is a high performance hydrogen which is steered to BDT and provide time signals for other subsystems of BDS.

Describe how the timescale transfers from the reference timescale to the system timescale and finally to the satellites. Include the nominal rate of SV update.

BDS monitors the offset between BDT and ground reference timescales in real-time, and generates the offset parameters which are broadcasted by navigation message. Update once an hour.

If any other pertinent details exist concerning the generation and realization of system and/or reference time, include them as well.

No.