Research on Key Issues and Metric Validation for BeiDou Navigation Satellite System International Civil Aviation Standards: Post-Print

Authors: Chen Ying, Lu Yun, Liu Cheng, Shao Bo, Zhang Jian, Yuan Bin

Date: 2022-01-14T14:36:46+00:00

Abstract

To promote the application of Global Navigation Satellite Systems (GNSS) in the international aviation domain, the International Civil Aviation Organization (ICAO) is conducting research, validation, and upgrade activities for Standards and Recommended Practices (SARPs) applicable to the BeiDou Navigation Satellite System (BDS), GPS, Galileo, and GLONASS. Since initiating ICAO standardization efforts in 2010, BDS has undergone 11 years of work, participated in over 50 technical meetings, submitted more than 90 technical documents comprising over a thousand pages, addressed over 2,000 issues, and closed 189 validation metrics. This paper focuses on discussing key issues in the international standardization advancement of BeiDou, including time and coordinate references, radio frequency signal characteristics, and space signal performance. The deviation between BeiDou Time (BDT) and international UTC is maintained within 50 ns (modulo 1 s), and the difference between the BeiDou Coordinate System (BDCS) and ITRF-2014 does not exceed 3 cm; analyses and validations were performed on the received power level, signal quality, and anti-jamming capability of BeiDou civil signals, and a BeiDou space signal distortion model was constructed; finally, the definitions and calculation methods for BeiDou service performance under the ICAO SARPs framework were clarified, and actual system data were utilized to verify that the BeiDou system space signal performance meets all design specification requirements. The above analyses, models, and validation results demonstrate that the BeiDou system possesses a solid foundation for temporal and spatial compatibility and interoperability, features high-quality RF signals with strong anti-jamming capabilities, satisfies all relevant metric requirements, and can provide high-safety, high-integrity navigation services for the international aviation domain. These achievements have been incorporated into the ICAO BDS SARPs, establishing a robust theoretical, standardization, and validation foundation for the internationalization of China' s BeiDou system and its promotion and application in

the civil aviation sector.

Full Text

Preamble

Research and Assessment on Key Issues of ICAO SARPs for BeiDou Navigation Satellite System

Chen Ying[1], Lu Jun[1], Liu Cheng[1], Shao Bo[2*], Zhang Jian[2], Yuan Bin[2]

[1]China Satellite Navigation Office, Beijing 100094, China
[2]The 20th Research Institute of CETC, Xi' an 710068, China

Abstract

To promote the application of Global Navigation Satellite Systems (GNSS) in international aviation, the International Civil Aviation Organization (ICAO) is conducting research, verification, and upgrading of Standards and Recommended Practices (SARPs) for BeiDou Navigation Satellite System (BDS), GPS, Galileo, and GLONASS. Since initiating ICAO standardization work in 2010, BDS has participated in over 50 technical meetings over 11 years, submitted more than 90 technical documents totaling over 1,000 pages, addressed over 2,000 issues, and closed 189 verification indicators. This paper focuses on key issues in the internationalization of BDS standards, including time and coordinate reference frames, radio-frequency signal characteristics, and signal-in-space performance. The deviation between BeiDou Time (BDT) and international UTC is maintained within 50 ns (modulo 1 s), and the difference between the BeiDou Coordinate System (BDCS) and ITRF-2014 does not exceed 3 cm. We analyze and verify the ground power level, signal quality, and anti-interference capability of BDS civil signals, and construct a BDS signal-in-space distortion model. Finally, we clarify the service performance definitions and calculation methods for BDS under the ICAO SARPs framework, and use actual system data to verify that BDS signal-in-space performance meets all design requirements. These analyses, models, and verification results demonstrate that BDS possesses excellent spatiotemporal compatibility and interoperability foundations, high RF signal quality, and strong anti-interference capabilities. The relevant content meets all specified requirements and can provide high-safety, high-integrity navigation services for international aviation. These results have been incorporated into the ICAO BDS SARPs, establishing a solid theoretical, standardization, and verification foundation for the internationalization of BDS and its promotion in civil aviation applications.

Keywords: BDS; ICAO SARPs; time and coordinate reference; radio-frequency signal characteristics; signal-in-space performance

---

1. Introduction

The International Civil Aviation Organization (ICAO) is a specialized agency of the United Nations responsible for international civil aviation affairs and an intergovernmental organization. The Civil Aviation Administration of China (CAAC) represents China in ICAO.

Within ICAO' s organizational structure, the Assembly is the highest authority, the Council is the permanent governing body responsible to the Assembly, and the Air Navigation Commission (ANC) under the Council is the functional body specifically responsible for satellite navigation services related to civil aviation. The Navigation Systems Panel (NSP), a subordinate body of the ANC, is specifically responsible for aviation navigation technology research and standards development.

The NSP is currently conducting research, verification, and upgrading of SARPs for BeiDou Navigation Satellite System (BDS), GPS, Galileo, and GLONASS. ICAO SARPs are unified international civil aviation rules formulated by ICAO based on the *Convention on International Civil Aviation*, aimed at promoting the development of international civil aviation and ensuring aviation safety.

In 2010, BDS initiated its ICAO standardization efforts. At the 37th ICAO Assembly in September 2010, CAAC formally submitted an application for BDS to enter ICAO standards. At the 192nd ICAO Council meeting in January 2011, ICAO agreed in resolution form to gradually incorporate BDS into ICAO standards. CAAC and the China Satellite Navigation Office (CSNO) jointly established the BeiDou ICAO Standardization Working Team to fully participate in SARPs revision work. As of November 2020, the team has participated in 50 technical discussions, including NSP working group meetings, verification working group teleconferences, and specialized technical discussions, submitted over 90 documents totaling more than 1,000 pages, answered more than 2,000 questions, and closed 189 verification indicators.

The successful completion of all technical validations for BDS performance indicators marks the completion of the most critical and primary work for formally incorporating BDS into ICAO standards. This achievement lays a solid foundation for comprehensively implementing China' s civil aviation standardization internationalization strategy, advancing the construction of a civil aviation powerhouse in the new era, establishing industrial standards for BDS, and comprehensively promoting aviation applications of BDS during the 14th Five-Year Plan period.

Throughout this 11-year process, BDS international civil aviation standardization research and development has involved extensive content. This paper focuses on key indicators in the internationalization of BDS standards, including time and coordinate reference frames, radio-frequency signal characteristics, and signal-in-space performance, to discuss the implementation of BDS in ICAO standards.

2. Reference Frames

2.1 Time Reference

The time reference for BDS is BeiDou Time (BDT). BDT uses the International System of Units (SI) second as its basic unit for continuous accumulation without leap seconds. The start epoch is 00:00:00 UTC on January 1, 2006. BDT is linked to international UTC through UTC(NTSC), and the deviation between BDT and international UTC is maintained within 50 nanoseconds (modulo 1 second). These requirements have been formally incorporated into ICAO BDS SARPs Section 3.1.4.4.

2.2 Coordinate Reference

The coordinate reference for BDS is the BeiDou Coordinate System (BDCS). The origin is at Earth' s center of mass, the Z-axis points toward the Reference Pole (IRP) defined by the International Earth Rotation and Reference Systems Service (IERS), the X-axis is the intersection line between the IERS-defined Reference Meridian (IRM) and the equatorial plane passing through the origin and orthogonal to the Z-axis, and the Y-axis forms a right-handed coordinate system with the Z and X axes. The geometric center of the BDCS reference ellipsoid coincides with Earth' s center of mass, and the rotation axis of the reference ellipsoid aligns with the Z-axis. The basic constants defining the reference ellipsoid are shown in Table 1.

Table 1. Parameters of BDCS Reference Ellipsoid

Parameters	Value
Semi-major axis	$a = 6378137.0\,\text{m}$
Geocentric gravitational constant	$\mu = 3.986004418 \times 10^{14}\,\text{m}^3/\text{sec}^2$
Flattening	$f = 1/298.257222101$
Earth' s rotation rate	$\dot{\Omega}_e = 7.2921150 \times 10^{-5}\,\text{rad/sec}$

The definition of BDCS is consistent with the International Terrestrial Reference Frame (ITRF). The difference between BDCS and ITRF-2014 does not exceed 3 cm (95%). The WGS-84 coordinate system adopted by GPS and Galileo in ICAO SARPs is also based on ITRF, and the difference between WGS-84 and BDCS is negligible in aviation applications. The definition of BDCS and its difference from ITRF/WGS-84 have been incorporated into ICAO BDS SARPs Section 3.1.4.5 and Appendix D Section 4.1.4.9.

3. RF Signal Characteristics

3.1 Ground Power Level

According to ICAO SARPs requirements for ground power level reception, under conditions of elevation angles above 5 degrees and using a 3 dBi linear circularly polarized antenna, the received ground power level for GPS L1C/A signals ranges from -158.5 dBW to -153 dBW, and for L5 signals from -157.9 dBW to -150 dBW. For GLONASS, the L1OF signal ground power level ranges from -161 dBW to -155.2 dBW, L1OC from -158.5 dBW to -155.2 dBW, and L3OC from -158.5 dBW to -155.2 dBW. For Galileo, the E1 signal ground power level ranges from -157.9 dBW to -151.45 dBW, and E5a from -155.9 dBW to -149.45 dBW.

The BDS Signal-in-Space Interface Control Document specifies the minimum ground power levels for B1I, B1C, and B2a signals but does not provide information on maximum levels. We calculated the maximum ground power levels for BDS at B1I, B1C, and B2a by considering satellite transmission power adjustment capability, antenna gain variations at different off-boresight angles, path loss differences caused by varying propagation distances, and atmospheric attenuation.

The BDS ground power levels at B1I, B1C, and B2a frequency points are shown in Table 2. The relevant requirements have been formally incorporated into ICAO BDS SARPs Sections 3.7.3.1.4.8.4, 3.7.3.1.4.9.4, and 3.7.3.1.4.10.4.

Table 2. B1I, B1C, and B2a Ground Level of BDS

Channel	Satellite Type	Received Power
B1I	MEO/IGSO	-163 dBW to -154.8 dBW
B1C	MEO/IGSO	-163 dBW to -156.5 dBW
B2a	MEO/IGSO	-159 dBW to -152.5 dBW

3.2 Signal Quality

Based on design requirements for BDS MEO and IGSO satellites, we conducted signal quality assessments from the perspectives of frequency domain characteristics, correlation domain characteristics, and modulation characteristics. The evaluation results are distributed as shown in Tables 3 and 4, with all test items meeting specification requirements.

Table 3. Signal Quality Evaluation of BDS MEO and IGSO Satellites

Test Item	Detail Requirements	Results
Frequency Characteristics	Spectral density with excess radiation power: 1) B1$±$45MHz ≤ -35 dBW/KHz2) B2$±$45MHz ≤ -35 dBW/KHz	-85.3 dB-88.8 dB
	Phase Noise: 1) -35 dBc/Hz @ 1 Hz2) -60 dBc/Hz @ 10 Hz3) -80 dBc/Hz @ 100 Hz4) -85 dBc/Hz @ 1 kHz5) -90 dBc/Hz @ 10 kHz6) -95 dBc/Hz @ 100 kHz	-91.03 dB-89.16 dB-54.07 dB-72.25 dB-83.21 dB-93.82 dB
	In-band spurious ≤ -50 dBc	-98.31 dB
Correlation Characteristics	Associated losses due to load distortion: 1) B1: 0.3 dB2) B2: 0.6 dB	0.086 ns0.057 ns
Modulation Characteristics	Zero crossing deviation of S curve ≤ 0.5 ns	-0.105 dB
	Signal component effective power ratio deviation ≤ 0.5 dB	0.014 dB
	Carrier phase deviation between signal components ≤ 0.1 rad	0.032 rad

3.3 Anti-Interference Capability

Anti-interference capability is a critical indicator for satellite navigation services. Relevant standards from ICAO, RTCA, ARINC, and FAA specify requirements for anti-interference performance. For GPS and GLONASS, the specifications state that under specific aviation electromagnetic interference environments, GPS pseudorange tracking accuracy is 0.36 m and GLONASS pseudorange tracking accuracy is 0.8 m. Under a standardized testing framework, BDS B1C and B2a signals demonstrate pseudorange tracking accuracies better than 0.5 m and 0.3 m (1σ), respectively, under various interference margins including limited-bandwidth white noise, continuous wave, and pulsed interference. The test results are shown in Figures 1 and 2. These test results have been recognized by ICAO NSP, and the relevant requirements have been formally incorporated into ICAO SARPs.

3.4 Signal-in-Space Distortion Model

Navigation satellite signals may experience distortion due to various unintended causes. This distortion poses potential threats to differential users and is typically monitored through signal quality monitoring methods. To evaluate the effectiveness of signal quality monitoring, it is necessary to develop limited modeling descriptions of signal distortion that specify the particular distortion characteristics and magnitudes that monitoring must address.

Currently, ICAO standards describe distortion for GPS and GLONASS navigation signals using the TM-A, TM-B, and TM-C models. For B1C and B2a signal characteristics and considering actual BDS satellite conditions, we analyzed the threat space parameters for the BeiDou distortion model (Δ, σ, fd parameters) based on three principles: (1) Parameter values exceeding physical satellite realizability are excluded from the threat space; (2) Parameter values causing excessive ranging errors that are easily detectable are excluded; and (3) Parameter values causing small differential errors between monitoring stations and user receivers that do not affect system service performance are excluded.

Considering strict design constraints for monitoring and user receivers, we analyzed the maximum differential errors caused by distortion through limited-range traversal. The relationships between BDS on-board ranging bias and parameter Δ under the TM-A model, and with parameter fd under the TM-B model, are shown in Figures 3 and 4, respectively. The TM-C model parameter range is a combination of TM-A and TM-B.

The threat space parameter ranges for BDS B1C and B2a signals under TM-A, TM-B, and TM-C distortion models are shown in Table 4. The BDS distortion model has been formally incorporated into ICAO SARPs Appendix D, Chapter 8.

Table 4. Threat Space for BDS B1C and B2a Signals

Signal	TM-A Model	TM-B Model	TM-C Model
BDS B1C	-0.05 $\leq \Delta \leq$ 0.05 (chip)0.1 $\leq \sigma \leq$ 20 (Mnepers/s)	1.5 $\leq$ fd $\leq$ 18 (MHz)	-0.5 $\leq \Delta \leq$ 0.5 (chip)0.1 $\leq \sigma \leq$ 18 (Mnepers/s)4 $\leq$ fd $\leq$ 18 (MHz)
BDS B2a	-0.05 $\leq \Delta \leq$ 0.05 (chip)0.1 $\leq \sigma \leq$ 20 (Mnepers/s)	1.5 $\leq$ fd $\leq$ 18 (MHz)	-0.5 $\leq \Delta \leq$ 0.5 (chip)0.1 $\leq \sigma \leq$ 18 (Mnepers/s)4 $\leq$ fd $\leq$ 18 (MHz)

4. BDS Signal-in-Space Performance

BDS signal-in-space performance design indicators are divided into four categories: (1) **Accuracy**, including global average horizontal/vertical accuracy and worst-point horizontal/vertical accuracy; (2) **Integrity**, including single-satellite and constellation integrity to characterize the probability of service failures; (3) **Continuity**, characterizing the probability that a "healthy" open service signal-in-space will continue operating without unscheduled interruption during a specified period; and (4) **Availability**, characterizing the probability that satellites at specified orbital positions provide "healthy" signal-in-space.

These performance indicators have been formally incorporated into ICAO SARPs. Based on data collected by monitoring receivers in China from July 1 to July 30, 2019, we verified the BDS global navigation satellite system signal-in-space performance indicators.

4.1 Accuracy

The BDS global navigation satellite system design specifications require global average horizontal accuracy of 6.0 m and global average vertical accuracy of 10.0 m; worst-point horizontal accuracy of 12.0 m and worst-point vertical accuracy of 22.0 m. Following the position error calculation method for global average and worst locations in the GPS SPS Performance Standard and considering BDS characteristics, the position error determination steps for BDS B1C and B2a open services are:

1. **Constellation configuration**:
   - Full constellation: 24 BDS-3 MEO satellites + 3 IGSO satellites
   - Two-satellite outage scenarios: Given the extremely low probability of two satellite failures at any moment in an orbital period, and considering the uniform distribution of 24 BDS-3 MEO satellites across three orbital planes with 120° separation, we consider cases where the two missing satellites are either in the same plane or in two different planes. Due to orbital symmetry (near-circular orbits), the following outage scenarios are analyzed: MEO-07/MEO-08, MEO-07/MEO-09, MEO-07/MEO-15, MEO-08/MEO-01, MEO-08/MEO-02, MEO-08/MEO-15, MEO-08/MEO-03, and MEO-08/MEO-04.
2. **Calculation conditions**: 5° mask angle, 5° × 5° grid points, 5-minute intervals, 7 × 24-hour period.
3. Calculate HDOP (Horizontal Dilution of Precision) and VDOP (Vertical Dilution of Precision) for each grid point globally over one period.
4. Statistically analyze HDOP and VDOP values for all grid points at 95% confidence level over one period.
5. Determine the mean and maximum (worst) values across all grid points.
6. Calculate position errors using:

$$\mathrm{SPP}(H) = \mathrm{UERE} \times \mathrm{HDOP}$$

$$\mathrm{SPP}(V) = \mathrm{UERE} \times \mathrm{VDOP}$$

The HDOP and VDOP statistics are shown in Table 5.

Table 5. Statistics (95%) of DOP

Constellation	Mean of HDOP	Mean of VDOP	Maximum of HDOP	Maximum of VDOP
24 MEO + 3 IGSO	1.14	1.92	2.2	4.3
2 satellites invalid	1.20	2.05	2.4	4.6

Using User Equivalent Range Error (UERE) as the root sum square of Signal-in-Space Range Error (SISRE) and User Equipment Error (UEE), with SISRE = 4.6 m (any age) and UEE = 2.0 m:

$$\text{UERE} = \sqrt{(4.6)^2 + (2.0)^2} = 5.0\,\text{m}$$

$$\text{SPP}(H)_{\text{WORST}} = 5.0 \times 2.2 = 11.0\,\text{m}$$

$$\text{SPP}(V)_{\text{WORST}} = 5.0 \times 4.3 = 21.5\,\text{m}$$

$$\text{SPP}(H)_{\text{AVE}} = 5.0 \times 1.14 = 5.7\,\text{m}$$

$$\text{SPP}(V)_{\text{AVE}} = 5.0 \times 1.92 = 9.6\,\text{m}$$

The global average horizontal accuracy is 5.7 m and vertical accuracy is 9.6 m; worst-point horizontal accuracy is 11.0 m and vertical accuracy is 21.5 m, meeting the signal-in-space accuracy requirements.

4.2 Integrity

Single-satellite integrity risk refers to the probability of a major service failure for any single satellite. The design requirement is that the probability of a user receiver antenna not receiving an alert within 300 seconds shall not exceed 1×10^{-5} per hour. Constellation integrity risk refers to the probability of major service failures occurring simultaneously on two or more satellites, with a design requirement of not exceeding 1×10^{-7} per hour.

Test data used B-CNAV1 and B-CNAV2 navigation message parameters from monitoring receivers in China during July 1-30, 2019, including satellite ephemeris, clock corrections, satellite health status (HS), data integrity flag (DIF), signal integrity flag (SIF), and system alert flag (AIF). The integrity analysis procedure:

1. Calculate radial, tangential, normal, and clock errors for each healthy satellite using broadcast and precise ephemeris (including clock corrections).
2. Calculate instantaneous SISRE:

$$\text{SISRE} = \sqrt{(\beta \times R - c \times T)^2 + \alpha^2 \times (A^2 + C^2)}$$

where R is radial error, C is normal error, A is tangential error, T is satellite clock error, c is the speed of light, β is a scale factor (0.99 for IGSO, 0.98 for MEO), and α is a scale factor (127 for IGSO, 54 for MEO).

3. For B1C/B2a frequencies, calculate SISA using SISAIoe (satellite orbit tangential and normal accuracy) and SISAIocb (satellite radial and clock accuracy), SISAIoc1 (satellite clock frequency drift accuracy index), and SISAIoc2 (satellite clock frequency drift rate accuracy index) from B-CNAV1 or B-CNAV2 navigation messages.
4. Compare each satellite' s SISRE value against $4.42 \times$ SISA limits.
5. Statistically analyze single-satellite integrity risk as the probability of SISRE exceeding limits; constellation integrity risk as the probability of two or more satellites simultaneously exceeding limits due to common causes.

Figures 5 and 6 show the relationship between $4.42 \times$ SISA limits and SISRE for some satellites. No single-satellite SISRE exceedances occurred, meeting the 1×10^{-5} per hour single-satellite integrity risk requirement. No simultaneous exceedances on two or more satellites due to common causes occurred, meeting the 1×10^{-7} per hour constellation integrity risk requirement.

4.3 Continuity

Signal-in-space continuity is the probability that a "healthy" open service signal-in-space will continue operating without unscheduled interruption during a specified period. The BDS IGSO and MEO satellite signal-in-space continuity requirement is better than 0.998 per hour for B1C and B2a signals.

Test data used B-CNAV1 and B-CNAV2 navigation messages from monitoring receivers in China during July 1-30, 2019. The continuity analysis procedure:

1. At any time t (fixed step $\leq$ 10 min), determine satellite signal health (availability) from navigation messages, denoted as H_{flag}, where $H_{\text{flag}} = 0$ indicates available signal.
2. At any time t, determine if a 48-hour advance notice of planned satellite outage was issued via BDS User Notice, denoted as $\text{BDUN}_{\text{flag}}$, where $\text{BDUN}_{\text{flag}} = 1$ indicates timely notification.
3. Identify any healthy satellite that becomes unhealthy without outage notification.
4. For each satellite, calculate continuity loss per hour with fixed step ($t_{\text{hour}} \leq$ 1 hour).
5. Annual average signal-in-space continuity for all satellites is the ratio of hour intervals without continuity loss to total hour intervals.

BDS signal-in-space continuity results are shown in Figure 7. The average continuity is 0.9982 per hour for IGSO satellites and 0.9983 per hour for MEO satellites on B1C and B2a frequencies, meeting design requirements.

4.4 Availability

Signal-in-space availability is the probability that satellites at specified orbital positions provide "healthy" signals, including both planned and unplanned outages. The BDS IGSO and MEO satellite signal-in-space availability requirement is better than 0.98 for B1C and B2a signals.

Test data used B-CNAV1 and B-CNAV2 navigation messages from monitoring receivers in China during July 1-30, 2019. The availability analysis procedure:

1. At any time t (fixed step $\leq$ 10 min), determine satellite signal health from navigation messages, denoted as H_{flag}.
2. Calculate average availability:

$$A_H = \frac{\sum_t \sum_{\text{SV}} (1 - H_{\text{flag}}(t, \text{SV}))}{N_{\text{SV}} \times N_t}$$

   where N_{SV} is the number of satellites (27 for the basic BDS constellation) and N_t is the total number of statistical samples.

BDS signal-in-space availability results are shown in Figure 8. The average availability is 0.9958 for IGSO satellites and 0.9954 for MEO satellites on B1C and B2a frequencies, meeting design requirements.

---

5. Conclusion

Since 2010, BDS international standardization work has progressed for over a decade. BDS international civil aviation standardization involves extensive efforts. This paper has focused on key indicators including time and coordinate reference frames, RF signal characteristics, and signal-in-space performance. Currently, the deviation between BDT and international UTC is maintained within 50 ns (modulo 1 s), and the difference between BDCS and ITRF-2014 does not exceed 3 cm. Evaluation results for BDS civil signal ground power level, signal quality, and anti-interference capability, along with the signal-in-space distortion model, all meet design specifications. Based on the service performance definitions and calculation methods under the ICAO SARPs framework, actual system data verifies that BDS signal-in-space performance meets all design requirements. These analyses, models, and verification results have been formally incorporated into ICAO SARPs. BDS has been in continuous operation since 2018 for three years, with stable service performance and all indicators consistent with ICAO SARPs requirements, significantly promoting BDS internationalization and standardization in civil aviation. Future work will continue to refine

BDS verification at the ICAO level and further advance validation at the aviation industry organization level to support the successful implementation of the "BDS Going Global" strategy.

References

[1] Civil Aviation Administration of China. BeiDou ICAO Standard Completes All Technical Verifications, Achieving Major Breakthrough. https://i.carnoc.com/detail/548451

[2] Xinhua News Agency. BeiDou ICAO Standard Completes All Technical Verifications, Achieving Major Breakthrough. http://www.xinhuanet.com/tech/2020-11/17/c_{1126751813}.htm

[3] China Satellite Navigation Office. BeiDou Navigation Satellite System Signal-in-Space Interface Control Document Open Service Signal B1C (Version 1.0). December 2017.

[4] Qin Zhi, Wang Zhipeng, Li Xiao, Liu Yuan. BDS SARPs V1.5. Navigation Systems Panel Joint Working Groups Sixth Meeting (Virtual Meeting), 8-18 June, 2020.

[5] Qin Zhi, Zhou Shanshi, Wang Zhipeng. Difference between BDS Terrestrial Reference Frame BDCS and ITRF2014. Navigation Systems Panel Joint Working Groups Fifth Meeting, Montréal, 15-24 October, 2019.

[6] ICAO. International Standards and Recommended Practices Annex 10 Aeronautical Telecommunications Volume I. July 2018.

[7] Ken Alexander, Tim Cashin, Barbara Clark, Karl Kovach, JP Fernow, and Todd Walter. Update to Annex 10 Changes for the GPS L5 Signals. Navigation Systems Panel Joint Working Groups Sixth Meeting (Virtual Meeting), 8-18 June, 2020.

[8] VWG Rapporteur. Proposed Amendments to Annex 10, Volume I: Global Navigation Satellite System (GLONASS) Provisions. Navigation Systems Panel Joint Working Groups Sixth Meeting (Virtual Meeting), 8-18 June, 2020.

[9] Eric Chatre, Natalia Castrillo. Galileo Open Service Draft SARPs. Navigation Systems Panel Joint Working Groups Sixth Meeting (Virtual Meeting), 8-18 June, 2020.

[10] Qin Zhi, Wang Pengfei, Lei Chengqian, et al. Interference Mask and Anti-Interference Testing for BDS B1C and B2a Signals. Navigation Systems Panel Joint Working Groups Fifth Meeting, Montréal, 15-24 October, 2019.

[11] Qin Zhi, Cui Xiaowei, Shao Bo, Ding Qun. BDS EWF SARPs. Navigation Systems Panel Joint Working Groups Sixth Meeting (Virtual Meeting), 8-18 June, 2020.

Figures

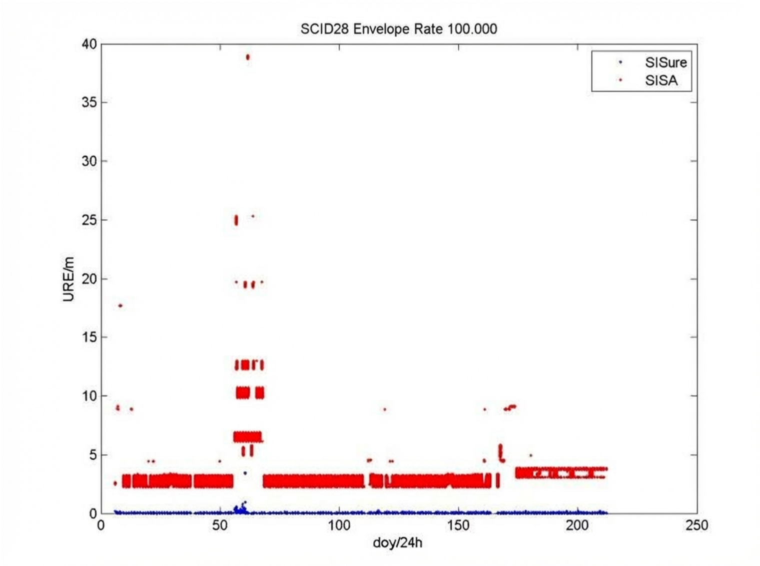

Figure 1: Figure 4

Source: ChinaXiv —Machine translation. Verify with original.

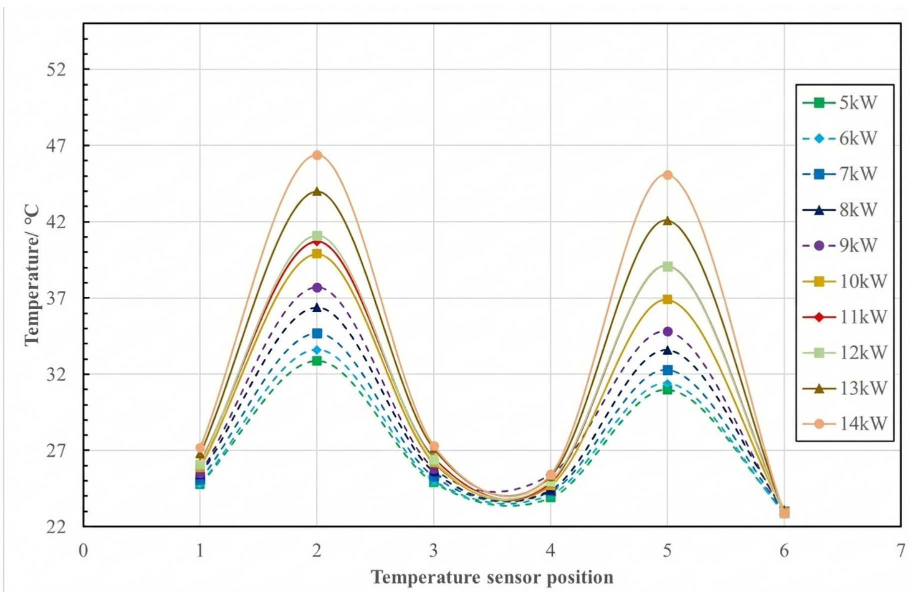

Figure 2: Figure 5