$C_S = 1 - \frac{T_{Non}}{T_{All}} \times 100\%$

A Preliminary Assessment on Continuity and Availability of Signal-In-Space for Multi-GNSS: From 2015 to 2016

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Abstract

Continuity and availability are important indicators of GNSS performance assessment. In this paper, uniform assessment criteria, models and algorithms are used to evaluate and compare the continuity and availability of GPS, GLONASS, Galileo, and BDS. A total of two years of data from 2015-2016 were used in the study. The results show that the average continuity of all satellites in GPS is 0.9996, and there is still a small gap between the requirements of GPS SPS (0.9998). The average availability of all satellites in GPS is 0.9903, which is better than the 0.957 proposed by GPS SPS. The continuity and availability of GLOANSS systems are 0.9999 and 0.9911, respectively, which are better than those of GPS SPS. The average continuity of all Galileo satellites was 0.9993, which did not reach the standard of GPS SPS PS. This may be due to the fact that the Galileo system newly launched satellites are still in orbit test. The average availability of 0.9990 is superior to that of GPS SPS. For BDS satellite navigation systems, the average continuity and availability of all satellites are 0.9979 and 0.9875, respectively, although both meet the requirements of the BDS standard service, but their continuity is much lower than that of GPS SPS. Continuity is the performance that BDS urgently needs to improve in system construction.

Data and Method

Assessment Method of SIS Continuity and Availability

（A ） SIS continuity

The ability of GNSS to continually serve satellite navigation users is navigation system continuity. A single satellite can continue to give users the ability to launch a certain precision navigation signal that single-satellite continuity, the continuity of the system is based on the single-satellite continuity.

For GPS continuity, SPS PS 2008 [1] gives the definition that the probability of a Signal-In-Space (SIS) being in a healthy state for a specified period of time without any unplanned

$$C_S = 1 - \frac{T_{Non}}{T_{All}} \times 100\% \quad (1)$$

Assuming that the test period is (T_{start}, T_{end}) and the sampling interval of the receiver is T , the calculation formula of the SIS continuity can be expressed as

$$C_S^{BDS} = \frac{\sum_{T=T_{Start},T}^{T_{end}-T_{op}} \left\{ \prod_{k=t,T}^{T+T_{op}} \mathrm{bool}(Statu) \right\}}{\sum_{T=T_{Start},T}^{T_{end}-T_{op}} \mathrm{bool}(Statu)} \quad (2)$$

（B ） SIS availability

The availability of GPS is generally classified as orbital availability and constellation availability according to the definition of SPS PS 2008 [1], both of which are closely related, and availability of orbital availability refers to the availability of the spatial signal of a single satellite, The key to the statistics and probability of single-satellite available time in the time domain lies in the statistics of Mean time between failure (MTBF) and Mean time to repair (MTTR).

Markov models are used to describe the availability of satellites. For the availability of a single satellite, as shown in Figure 1, (1) indicates the normal state of the satellite and (0) indicates the satellite fault state, wherein the fault state is further divided into four situations, that is, orbital maneuver, single particle, moving zero deflection and other reasons, respectively A1, A2, A3 and A4.

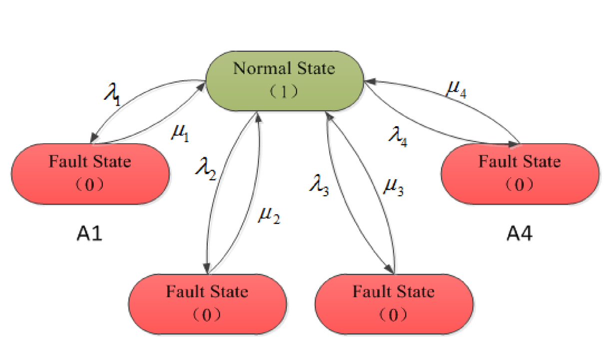

Figure 1 The Markov state transition process

$$A_i(\infty) = \frac{\mu_i}{\lambda_i + \mu_i}, \quad i = 1,2,3,4 \quad (4)$$

Considering the impact of various types of disruptions, the satellite's failure ratio and repair ratio are respectively

$$\begin{cases} \lambda = \lambda_1 + \lambda_2 + \ldots + \lambda_4 \\ \mu = \dfrac{\lambda_1 + \lambda_2 + \ldots + \lambda_4}{\dfrac{\lambda_1}{\mu_1} + \dfrac{\lambda_2}{\mu_2} + \ldots + \dfrac{\lambda_4}{\mu_4}} \end{cases} \quad (5)$$

Results and Discussions

In order to compare the continuity and availability of multi-GNSS, X and Y are used in Fig. 10 respectively for continuity and usability indicators. Based on this, a comprehensive analysis of performance is carried out. In the picture below, the blue circle represents the GPS satellite, the green circle represents the GLONASS satellite, the red circle represents the BDS satellite and the black circle represents the Galileo satellite. From the figure we can get the GLONASS satellite shows excellent performance in continuity and usability. GPS and Galileo show the second best performance. For the BDS system, its availability is comparable to that of the other three systems, but its continuity is far behind. Table 1 shows the average of four navigation systems. The system with the best average continuity is GLONASS, and the best average usability is Galileo. While BDS has the worst continuity and usability.

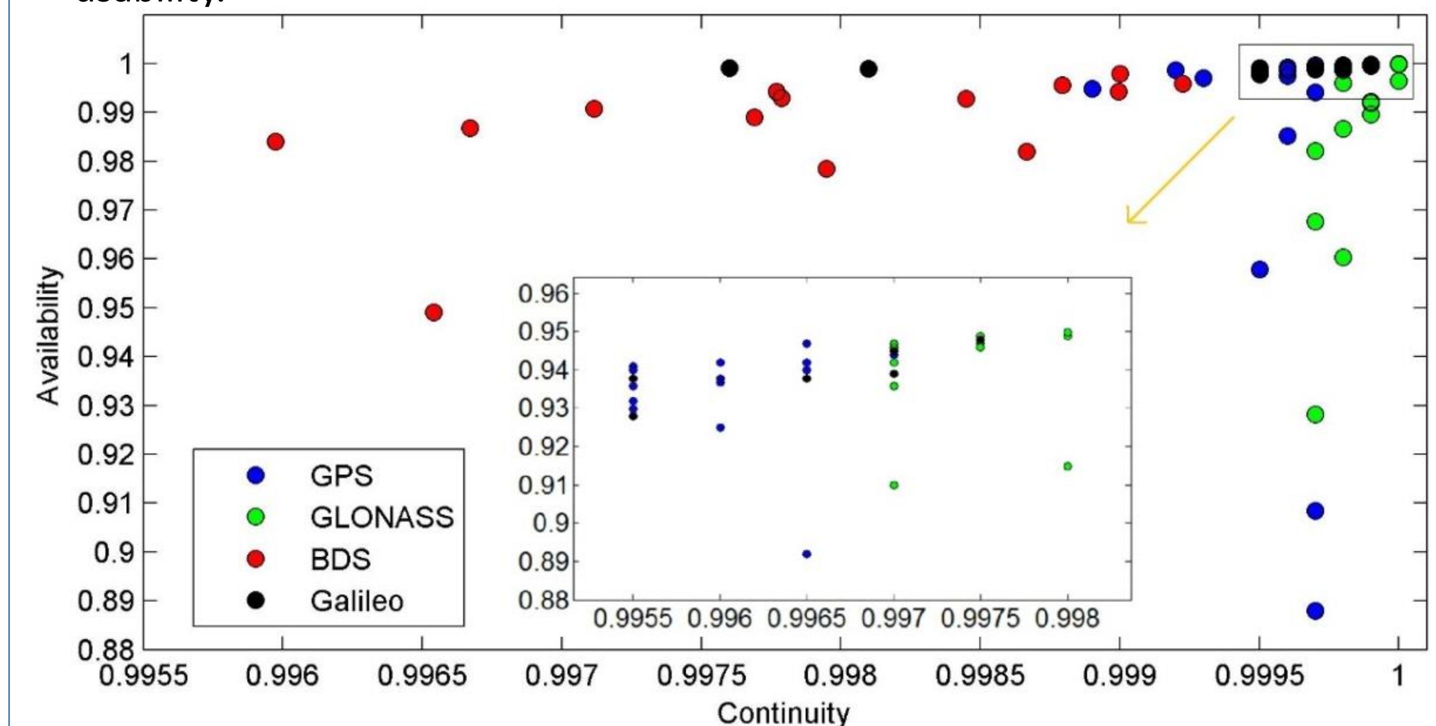

Figure 2 Continuity and availability of multi-GNSS

Table 1 Average continuity and availability of multi-GNSS

GNSS	Average continuity	Average availability
GPS	0.9996	0.9903
GLONASS	**0.9999**	0.9911
BDS	0.9979	0.9875
Galileo	0.9993	**0.9990**

Conclusions

By evaluating the results we can get the following conclusions.

- (1) The continuity and availability of GPS space signals do not meet the requirements of the standard service specification, which needs to be further improved.
- (2) The continuity and availability of GLONASS and Galileo are better than GPS, although they are not officially given a standard;
- (3) The continuity and availability of BDS can meet the standard of BDS space signal service, but there is still a big gap from GPS SPS PS 2008 standard. In particular, continuity needs to be further improved in system construction.

In summary, the continuity and availability of multi-GNSS can be better understood through continuity and usability assessments. This not only provides an important reference for navigation users, but also provides navigation system builders with an improved direction. This article's assessment is for GNSS satellite SIS only. The authors plan to design new continuity and usability metrics in the future to evaluate the continuity and availability of all GNSS satellites for actual positioning.

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Reference

[1] DoD，Global Positioning System Standard Positioning Service Performance Standard, Version 4, September 2008.
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[3] DoT，GPS Civil Monitoring Performance Specification, April 2009.
[4] Dellago.GALILEO-GPS interoperability and compatibility's synergetic viewpoint. ION GPS/GNSS2003. Portland OR，2003: 542-548.