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Space systems — Space based services requirements for centimetre class positioning

Systèmes spatiaux — Exigences de services fondés sur l'espace pour le positionnement de la classe centimètre

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicle*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Nowadays, applications such as civil engineering, automatic farming, traffic control, and disaster monitoring system need centimetre class positioning. This centimetre class positioning is deeply concerned with various fields of our daily life.

Especially the positioning system of applications for the construction and civil engineering, surveying and mapping, and water level measuring for river or ocean, requires certifying the reliability of positioning system. Also, the case of automatic vehicle driving, ship control, and snowplow on the road demands the centimetre class positioning capability which is available in real-time and over wide area.

This International Standard intends to standardize the system requirements and verification criteria for centimetre class positioning over a wide area by broadcasting augmentation data through satellites, in order that we can enhance the availability of related applications and improve our daily life.

The services broadcasting augmentation data through satellite or satellite-based augmentation system (SBAS), such as WAAS, EGNOS, and MSAS, are currently in operation for aviation. This SBAS claims the positioning accuracy of meter level and focuses on high integrity. Also, the SBAS is mainly operated by a state agency for the sake of human life and internationality of aviation.

On the other hand, the services in this International Standard such as precise point positioning (PPP) require the positioning accuracy at centimetre level. There are now a number of providers supplying different sets of PPP corrections. At the same time, this PPP covers different markets such as civil engineering, automatic farming, and automatic driving. PPP began to outpace SBAS for some applications requiring higher precision. Therefore, it is inevitably essential to ensure and certify the reliability of the PPP system.

As stated above, from the viewpoint of benefit, it is clear that PPP services continue to evolve and become more and more sophisticated to match the growing complexity of customer applications.[7] On the other hand, in view of rationale, there have been some great strides in overcoming the convergence time challenge and there are currently some successful real-time PPP applications both academic and commercial.[8] The objective of this International Standard is to establish the space based services by broadcasting the augmentation data for centimetre class positioning over wide area. Also, this International Standard defines the requirements for verification and evaluation of the guarantee of quality of the services, and therefore, this International Standard plays a role of the recognition for the certification of these services as well.

Space systems — Space based services requirements for centimetre class positioning

1 Scope

This International Standard defines the requirements for the wide area centimetre class positioning system by broadcasting augmentation data through satellites as follows.

— Centimetre class positioning

According to the progress of requirements for positioning services such as automatic farming, mapping and others, centimetre class positioning is very useful.

— Wide area positioning

It is quite effective to broadcast augmentation data through satellites for users over wide area such as a square, more than 1,000 km each side, anytime and anywhere. Even if this area is short of data network, additional ground network facilities are not needed. In addition, as ranging signal and augmentation data can be received from satellite broadcasting at the same time, it is unnecessary for user terminals to receive the signal such as transmitted by ground network.

— Real-time property

The user terminals need to resolve the ambiguity in real-time, using augmentation data broadcast from satellites or other means, for the realization of centimetre class positioning. On the other hand, the provider sides have to broadcast augmentation data such that the terminal sides are able to resolve the ambiguity in real-time.

2 Normative references

No normative references cited in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
fixing
determining the integer number of carrier phase waves when calculating the position by use of carrier phase measurement

Note 1 to entry: This should be distinguished from the case of determining the desired value by convergence of continuous quantities when calculating the position by use of pseudorange measurement.

3.2
sustainability
measurement anomaly at some reference point should make no influence on the augmentation data generation

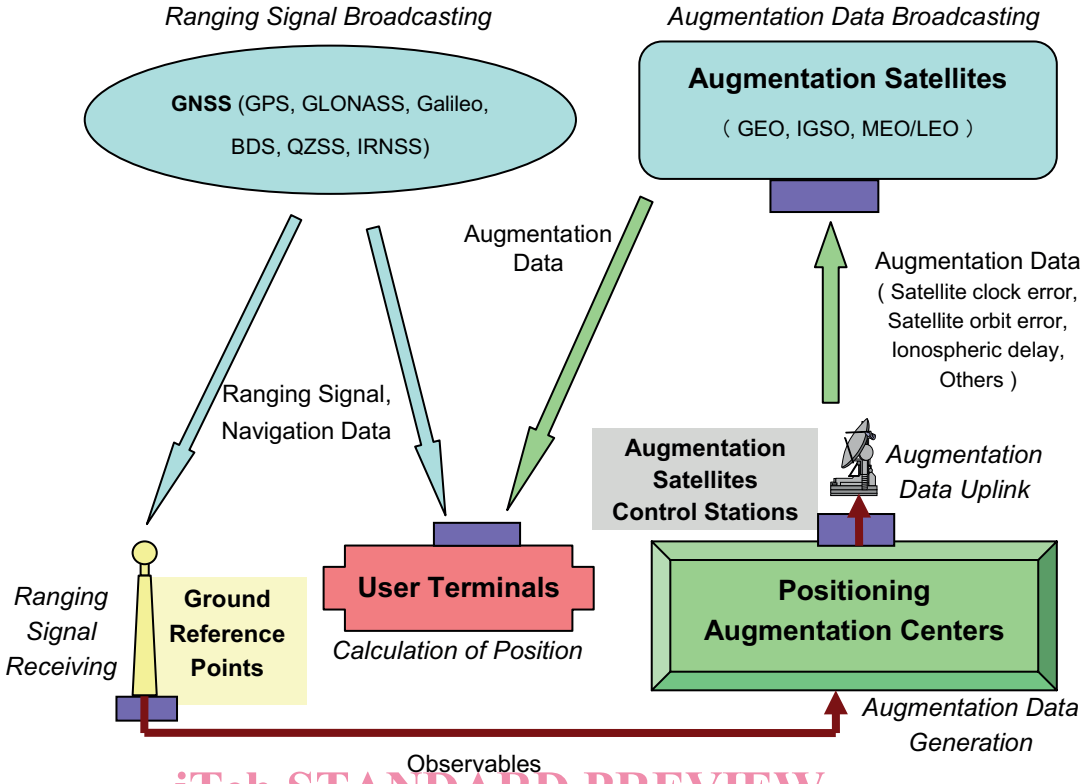
4 Abbreviated terms

BDS	BeiDou Navigation Satellite System
CEP	Circular Error Probable
DOP	Dilution of Precision
ECEF	Earth-Centred Earth-Fixed
ECI	Earth-Centred Inertial
GEO	Geostationary Earth Orbit
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IGSO	Inclined Geosynchronous Satellite Orbit
IOD	Issue Of Data
IRNSS	Indian Regional Navigational Satellite System
ITRF	International Terrestrial Reference Frame
ITS	Intelligent Transportation System
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
NED	North East Down
NRTK	Network Real-Time Kinematics
RTK	Real-Time Kinematics
QZS	Quasi-Zenith Satellite
QZSS	Quasi-Zenith Satellite System

5 Positioning augmentation system overview

5.1 System configuration

Figure 1 shows the typical view of positioning augmentation system of centimetre class. Here, this International Standard does not deal with the ranging signal broadcast from GNSS.



NOTE Bold: facilities, italic: primary functions, normal: signal/data.

Figure 1 — Typical augmentation satellite system for centimetre class positioning

This typical system is configured mainly by the following components:

a) GNSS;

b) augmentation satellites;

c) augmentation satellites control stations;

d) ground reference points;

e) positioning augmentation centres;

f) user terminals.

Each component is explained below.

5.2 Classification of augmentation satellites

An augmentation satellite broadcasts augmentation data, uplinked from the positioning augmentation centres for users over wide area. Augmentation satellites are classified into the following:

a) geostationary earth orbit satellite (GEO);

b) inclined geosynchronous satellite orbit (IGSO);

c) medium or low earth orbit satellite (MEO/LEO).

The overview and features of various augmentation satellites is shown in Table 1.

Table 1 — Overview and features of various augmentation satellites

No.	Satellites class	Orbit height (km)	Observed time per satellite (hr)	Available region	Features
1	GEO	36 000	24	Restricted to low latitude	Operational with one satellite
2	IGSO	around 36 000	8	Available for low, middle, and high latitude	Several satellites are needed to hand over several times a day for users to receive the signal continuously
3	MEO/LEO	< 36 000	<8	Available for low, middle, and high latitude	A lot of satellites are needed to hand over more frequently for users to receive the signal continuously than IGSO

5.3 Positioning augmentation centres

The augmentation centres make augmentation data using the observation data at the ground reference points. The system sustainability is taken into account when making augmentation data. Some remarks are described below about the functions and conditions, message structure, and user operational support service.

5.3.1 Functions and conditions of the positioning augmentation centres

The functions and conditions of the positioning augmentation centres are as follows.

a) Augmentation data generation

The augmentation centres make augmentation data using the observation data at the ground reference points.

b) Monitoring of operation and measures

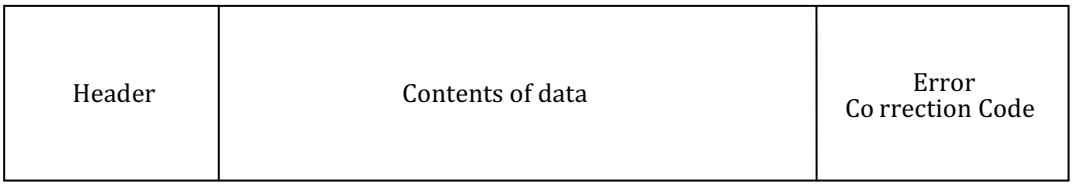
The augmentation centres monitor the system operational conditions by analysing data received from augmentation satellites and reference points so as to detect ionosphere disturbance or others. Based on the result, this International Standard should assess the influence on ranging signal or communication link and takes proper measures to recover the situation.

c) Detection of satellite signal anomaly

The augmentation centres calculate the predicted error using observation data at the ground reference points. The signal analysis is provided to specify the malfunction satellite.

5.3.2 Message structure

Figure 2 shows the example of message structure of augmentation data broadcast from the augmentation satellite.



NOTE The header contains preamble, satellite number, station number, and message number. The contents of data correspond to the corrections, that is, satellite clock error, satellite orbit error, ionospheric delay, the status parameters, and ancillary data, such as those listed in Table F.1. The message format contains the error correction code, such as a cyclic redundancy code, so as to decode the message correctly.

Figure 2 — Message structure

5.3.3 User operational support service

The system should provide useful information for user terminals as follows.

a) Estimation of positioning error.

b) Condition of ionosphere, such as disturbance of ionosphere.

c) Condition of troposphere, such as anomaly of water vapour as caused by local rainfall, resulting in the positioning error due to tropospheric delay mismatch.

5.4 Operation

Some remarks on the operation of positioning augmentation system are as follows.

5.4.1 Simultaneous operation

The centimetre class augmentation data can also be used as the meter class augmentation data at the same time. Therefore, this system enhances the operational variation.

5.4.2 Various fields of application

A variety of industrial fields required for centimetre class positioning is illustrated in Annex G.

6 Requirements for positioning augmentation system

6.1 Requirements for augmentation satellites

Requirements for augmentation satellites of various orbits are described below.

a) Orbit constellation

b) Numbers of satellites

c) Antenna coverage

This means a part on the earth where the transmission signal from the augmentation satellite can be reached.

d) Transmission signal characteristics

Over the targeted area, under the condition of the minimum elevation angle of the augmentation satellite, this International Standard establishes the requirements for orbit constellation (satellite number/orbit plane/phase difference between orbit planes).

The examples of orbit constellation of augmentation satellites are shown in Annex D. Corresponding to the respective orbit constellation, the ground track and the antenna coverage are shown in Annex E.

6.2 Requirements for augmentation satellites control stations

Augmentation satellite control stations shall track and control the augmentation satellite so that it might broadcast augmentation data for users correctly. Requirements for satellite control stations are described as follows.

a) Allowable broadcasting latency of augmentation data

The allowable broadcasting latency of augmentation data shall be determined for the following parameters:

Latency from ground reference points to positioning augmentation centre	d1[sec]
Latency from positioning augmentation centre to satellites control station	d2[sec]
Latency from satellites control station to augmentation satellite	d3[sec]
Latency from augmentation satellite to user terminals	d4[sec]
Total latency time	d1+d2+d3+d4 [sec]

For typical example, d1, d2, d3, and d4 are 1 s, 1 s, 2 s, and 2 s, respectively.

b) Switch of augmentation data between satellites

In the case of switching augmentation satellites which broadcast the augmentation data for the prescribed area, the procedure for the handover of the augmentation data between relevant satellites shall be established.

c) Preparation for anomaly in space

The satellites control station shall detect anomaly in space environment or satellite orbits and embed the alert message or disabled satellites data into the broadcasting signal.

6.3 Requirements for ground reference points

The functions and conditions required for ground reference points shall be shown as follows.

a) Requirements for output signal

— Pseudorange

— Carrier phase

— Signal strength

The information such as data acquisition rate cycle slip, multi-path, shall be used as effectiveness criterion for augmentation data generation. The following data can be used for verification of the correctness of augmentation data, which is an optional service that is not necessarily operated by the ground reference point:

— augmentation data;

— positioning results;

— S/N of ranging signal;

