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Approved by：Yang Zhenmei

China Civil Aviation Technical Standard Order

This China Civil Aviation Technical Standard Order (CTSO) is issued according to Part 37 of the China Civil Aviation Regulations (CCAR-37). Each CTSO is a criterion which the concerned aeronautical materials, parts or appliances used on civil aircraft must comply with when it is presented for airworthiness certification.

Independent BDS Airborne Navigation Equipment

1. Purpose

This China Civil Aviation Technical Standard Order (CTSO) is applicable to the manufacturer of the Project Approval for application of CTSO authorization (CTSOA) for Independent BDS (BeiDou Navigation Satellite System) Airborne Navigation Equipment. This CTSO specifies the minimum performance standards (MPS) that Independent BDS Airborne Navigation Equipment must meet in order to be approved and identified using the applicable CTSO markings.

2. Applicability

This CTSO affects new application submitted after its effective date. Major design changes to article approved under this CTSO will require a new authorization in accordance with section 21.353 of CCAR-21-R4.

3. Requirements

Equipment manufactured on or after the effective date of this CTSO and intended to be identified using this CTSO marking must meet the minimum performance standards set forth in Appendix 1 and/or 2 of this CTSO.

a. Functionality.

This CTSO standard applies to independent BeiDou Navigation Satellite System (BDS) airborne equipment used in the en-route phase of aircraft certified according to CCAR-23, CCAR-25, CCAR-27, CCAR-29 and CCAR-31. The equipment types are divided into two categories: Beta and Gamma.

(1) Class Beta equipment

Consisting of independent BDS sensors, this type of equipment is expected to provide information such as position/velocity/time (PVT) to other terminal equipment.

Note: Considering the different application scenarios or uses of navigation information, when other terminal equipment is a non-airborne avionics interface, a data interface unit can be selected to convert the airborne avionics interface of the BDS sensor into a non-airborne avionics interface, at this time, the data interface unit is included in the Beta category equipment for approval and cannot be used alone.

(2) Class Gamma equipment

Equipment consisting of BDS sensors and other necessary components with en route navigation capability and display function.

Note: For aircraft with navigation, this type of equipment can be used as a supplemental navigation device; for aircraft without other navigation, the information displayed by this type of equipment can be used as the main position reference of the aircraft.

b. Failure Condition Classifications.

(1) Failure of the Class Beta equipment function defined in Section 3.a of this CTSO is a minor failure condition if it causes erroneous information.

(2) Loss of the Class Beta equipment function defined in Section 3.a of this CTSO is a failure condition without safety impact.

(3) There is no standard failure condition for class Gamma equipment function defined in Section 3.a of this CTSO. The applicable failure condition category for equipment depends on its intended use in a particular aircraft. Document the loss of function and malfunction failure condition classification for which the equipment is designed.

(4) The Design Assurance Level of the equipment shall at least correspond to this failure condition classification.

c. Functional Qualification.

The test conditions specified in Appendix 1 and Appendix 2 of this CTSO shall prove that the performance of the equipment meets the requirements.

d. Environmental Qualification.

According to the test conditions in Appendix 3 of this CTSO, the standard environmental conditions and test procedures applicable to the equipment shall be adopted to prove that the performance of the equipment meets the requirements. In addition to RTCA/DO-160G, the applicant may also adopt other standard environmental conditions and test procedures applicable to stand-alone BDS airborne navigation equipment.

Note 1：Some performance requirements in Appendix 1 and 2 are not required to be tested under all conditions contained in RTCA/DO-160G. If it can be shown that these specific performance parameters are not easily affected by environmental conditions according to calculation analysis, comparative analysis of similar designs, etc. and that the performance levels specified in Appendix 1 and/or 2 are not significantly reduced by exposure to such special environmental conditions, then this Class tests can be ignored.

e. Software Qualification.

If the article includes software, develop the software according to RTCA/DO-178C, Software Considerations in Airborne Systems and Equipment Certification, dated December 13, 2011, including referenced supplements as applicable, to at least the software level consistent with the failure condition classification defined in paragraph 3.b of this CTSO. The applicant may also develop the software according to RTCA/DO-178B, dated December 1, 1992.

f. Electronic Hardware Qualification

If the article includes complex custom airborne electronic hardware, develop the component according to RTCA/DO-254, dated April 19, 2000, Design Assurance Guidance for Airborne Electronic Hardware, to at least the design assurance level consistent with the failure condition classification defined in paragraph 3.b of this CTSO. For custom airborne electronic hardware determined to be simple, RTCA/DO-254, paragraph 1.6 applies.

g. Deviations

For using alternative or equivalent means of compliance to the criteria in this CTSO, the applicant must show that the equipment maintains an equivalent level of safety. Apply for a deviation under the provision of 21.368(a) in CCAR-21-R4.

4. Marking

a. Mark at least one major component permanently and legibly with all the information in 21.423(b) of CCAR-21-R4. The marking must include the serial number.

b. Also, mark the following permanently and legibly, with at least the manufacturer’s name, subassembly part number, CTSO number, class and subclass identification.

(1) Each component that is easily removable (without hand tools); and,

(2) Each subassembly of the article that manufacturer determined may be interchangeable.

c. If the article includes software and/or airborne electronic hardware, then the article part numbering scheme must identify the software and airborne electronic hardware configuration. The part numbering scheme can use separate, unique part numbers for software, hardware, and airborne electronic hardware.

d. The applicant may use electronic part marking to identify software or airborne electronic hardware components by embedding the identification within the hardware component itself (using software) rather than marking it on the equipment nameplate. If electronic marking is used, it must be readily accessible without the use of special tools or equipment.

5. Application Data Requirements

The applicant must furnish the responsible certification personnel with the related data to support design and production approval. The application data include a statement of conformance as specified in section 21.353(a)(1) in CCAR-21-R4 and one copy each of the following technical data:

a. A Manual(s) containing the following:

(1) Operating instructions and equipment limitations sufficient to describe the equipment's operational capability.

(2) Describe in detail any deviations.

(3) Installation procedures and limitations sufficient to ensure that the equipment, when installed according to the installation or operational procedures, still meet this CTSO's requirements. Limitations must identify any unique aspects of the installation. The limitations must include a note with the following statement:

"This article meets the minimum performance and quality control standards required by a CTSO. Installation of this article requires separate approval."

(4) For each unique configuration of software and airborne electronic hardware, reference the following:

(i) Software part number including revision and design assurance level;

(ii) Airborne electronic hardware part number including revision and design assurance level;

(iii) Functional description.

(5) A summary of the test conditions used for environmental qualifications for each component of the article. For example, a form as described in RTCA/DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*, Appendix A.

(6) Schematic drawings, wiring diagrams, and any other documentation necessary for installation of the airborne equipment.

(7) List of replaceable components, by part number, that makes up

the airborne equipment. Include vendor part number cross-references, when applicable.

b. Instructions covering periodic maintenance, calibration, and repair, for the continued airworthiness of the airborne equipment. Include recommended inspection intervals and service life, as appropriate.

c. If the article includes software: a plan for software aspects of certification (PSAC), software configuration index, and software accomplishment summary.

d. If the article includes simple or complex custom airborne electronic hardware: a plan for hardware aspects of certification (PHAC), hardware verification plan, top-level drawing, and hardware accomplishment summary (or similar document, as applicable).

e. A drawing depicting how the article will be marked with the information required by paragraph 4 of this CTSO.

f. Identify functionality or performance contained in the article not evaluated under paragraph 3 of this CTSO (that is, non-CTSO functions). Non-CTSO functions are accepted in parallel with the CTSO authorization. For those non-CTSO functions to be accepted, the applicant must declare these functions and include the following information with CTSO application:

(1) Description of the non-CTSO function(s), such as performance specifications, failure condition classifications, software, hardware, and

environmental qualification levels. Include a statement confirming that the non-CTSO function(s) don't interfere with the article's compliance with the requirements of paragraph 3.

(2) Installation procedures and limitations sufficient to ensure that the non-CTSO function(s) meets the declared functions and performance specification(s) described in paragraph 5.f.(1).

(3) Continued airworthiness requirements for non-CTSO functions described in section 5.f.(1) of this CTSO.

(4) Interface requirements and applicable installation test procedures to ensure compliance with the performance data defined in paragraph 5.f.(1).

(5) (if applicable) Test plans, analysis and results, as appropriate, to verify that performance of the hosting CTSO article is not affected by the non-CTSO function(s).

(6) (if applicable) Test plans, analysis and results, as appropriate, to verify the function and performance of the non-CTSO function(s) as described in paragraph 5.f.(1).

g. The quality system description required by section 21.358 of CCAR-21-R4, including functional test specifications. The quality system should ensure that it will detect any change to the approved design that could adversely affect compliance with the CTSO MPS, and reject the article accordingly.

h. Material and process specifications list.

i. List of all drawings and processes (including revision level) that define the article's design.

j. Manufacturer's CTSO qualification report showing results of testing accomplished according to paragraph 3.c of this CTSO.

6. **Manufacturer Data Requirements.**

Besides the data given directly to the authorities, have the following technical data available for review by the authorities:

a. Functional qualification specification used to identify each piece of equipment for compliance with the requirements of this CTSO.

b. Equipment calibration procedures.

c. Schematic drawings.

d. Wiring diagrams.

e. Material and process specifications.

f. The results of the environmental qualification tests conducted according to paragraph 3.d of this CTSO.

g. If the equipment contains software, provide relevant documentation as specified in RTCA/DO-178B or DO-178C, including all materials supporting the applicable objectives of RTCA/DO-178B or DO-178C Annex A “Process Objectives and Outputs for Software Levels”.

h. If the article includes complex custom airborne electronic hardware, the appropriate hardware life cycle data in combination with design assurance level, as defined in RTCA/DO-254, Appendix A, Table A-l. For simple custom airborne electronic hardware, the following data: test cases or procedures, test results, test coverage analysis, tool assessment and qualification data, and configuration management records, including problem reports.

i. If the article contains non-CTSO function(s), the applicant must also make available items 6.a through 6.h as they pertain to the non-CTSO function(s).

7. Furnished Data Requirements

a. If furnishing one or more articles manufactured under this CTSO to one entity (such as an operator or repair station), provide one copy or technical data and information specified in paragraphs 5.a and 5.b of this CTSO. Add any data needed for the proper installation, certification, use, or for continued compliance with the CTSO of the airborne equipment.

b. If the article contains declared non-CTSO function(s), include one copy of the data in paragraphs 5.f.(1) through 5.f.(4).

8. Availability of Referenced Documents

a. Order RTCA documents from:

Radio Technical Commission for Aeronautics, Inc.

1150 18th Street NW, Suite 910, Washington D.C. 20036

You may also order them online from the RTCA Internet website at:

www.rtca.org.

b. Copies of the BD file can be downloaded at :

www.beidou.gov.cn.

Appendix 1 Minimum Performance Standards for Class Beta Equipment

1.0 Purpose and Scope

1.1 Introduction

This appendix contains the minimum performance standards for Class Beta airborne equipment in the Independent BDS Airborne Navigation Equipment. The equipment is composed of an independent BDS sensor. It only has the function of a positioning sensor, which can provide data such as position and integrity, and ensure the integrity through the RAIM algorithm. This standard applies only to single-frequency (B1C) airborne self-contained navigation sensor devices that are not augmented by ground-based or satellite-based systems. BDS equipment under ground-based or satellite-based augmentation will be specified in other standards.

Inasmuch as the measured values of equipment performance characteristics may be a function of the measurement method, standard test conditions and methods of test are recommended in this document.

1.2 System Characteristics

1.2.1 BDS Signal Characteristics

The signal transmitted by each BDS satellite is modulated with data that define the satellite's position, the BDS time, its clock error and the health and accuracy of the transmitted data and ranging signals. The user equipment calculates a pseudorange to the satellite by timing the arrival of the BDS signal. The user equipment uses the pseudoranges from the satellites to calculate the receiver's internal clock offset and three dimensional position fix.

For detailed BDS signal characteristics and service information, please refer to *BeiDou Navigation Satellite System Public Service Performance Specification* (Version 3.0, May 2021) and *BeiDou Navigation Satellite System Signal-in-Space Interface Control Document Public Service Signal B1C* (Version 1.0, December 2017).

Note: For undated references, the latest version applies to this standard; for dated references, all subsequent revisions are not applicable to this standard.

1.2.2 Operation Goals

The operational goal of the equipment is to provide airborne independent navigation systems with position and integrity information for oceanic/remote continental en route and terrestrial en route phases of flight. Navigation integrity is provided by the RAIM algorithm for en route phases of flight. If the aircraft uses equipment conforming to this standard for IFR (Instrument Flight Rules) operations, it must also be equipped with another navigation equipment.

1.2.3 BDS Sensors

The accuracy and integrity of BDS sensors shall comply with the Appendix 1.

1.2.4 Satellite Selection

Satellite selection may be accomplished based on accuracy, geometry, signal quality, data quality, measurement quality, flight phase or other considerations. As automatic satellite selection is provided, the equipment must verify the validity of the satellite data.

1.3 Integrity and Definition of Key Terms

1.3.1 General Terms

System Integrity： System integrity refers to the ability of the system to provide timely warnings to users when the system should not be used for navigation.

Availability: The availability of a navigation system is the ability of the system to provide the required function and performance at the initiation of the intended operation. Availability is an indication of the ability of the system to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from external sources are available for use. Availability is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities.

Continuity： The continuity of a system is the ability of the total system (comprising all necessary elements to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation and was predicted to operate throughout the operation.

Horizontal Figure of Merit ($HFOM_P$): The $HFOM_P$ is the radius of a circle in the horizontal plane (the local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, that describes the region assured to contain the indicated horizontal position with at least a 95% probability under fault-free conditions at the time of applicability.

Misleading Information: Within this standard, misleading information is defined as any data that is output to other equipment or displayed to the pilot that has an error larger than the horizontal alert limit (HAL) or current horizontal protection level (HPL), without an indication of the error (e.g, flag) within the time-to-alert for the applicable phase of flight. This includes all horizontal position output data.

1.3.2 Alert Limits and Protection Levels

The Horizontal Alert Limit (HAL): The Horizontal Alert Limit (HAL) is the radius of a circle in the horizontal plane (the local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, that describes the region that is required to contain the indicated horizontal position with the required probability for a particular navigation mode (e.g.10^{-7} per flight hour for en route), assuming the probability of a BDS satellite integrity failure being included in the position solution is less than or equal to 10^{-4} per hour.

Horizontal Protection Level$_{\textbf{Fault Detection}}$ (HPL$_{\textbf{FD}}$): The Horizontal Protection Level$_{\text{Fault Detection}}$ (HPL$_{FD}$) is the radius of a circle in the horizontal plane (the local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, that describes the region assured to contain the indicated horizontal position. It is a horizontal region where the missed alert and false alert requirements are met for the chosen set of satellites when autonomous fault detection is used. It is a function of the satellite and user geometry and the expected error characteristics: it is not affected by actual measurements. Its value is predictable given reasonable assumptions regarding the expected error characteristics.

The Horizontal Uncertainty Level (HUL): The Horizontal Uncertainty Level (HUL) is an estimate of horizontal position uncertainty, based on measurement inconsistency, that bounds the true error with high probability (at least 99.9 percent). This estimate will not be available if there are four or fewer measurements available (because there is no redundancy).

Horizontal Exclusion Level$_{\textbf{Fault Detection}}$ (HEL$_{\textbf{FD}}$): The Horizontal Exclusion Level$_{\text{Fault Detection}}$ (HEL$_{FD}$) is the radius of a circle in the horizontal plane, where the missed alert and failed exclusion requirements can be met when autonomous Fault Detection and Exclusion is used (i.e., exclusion is available). It is only a function of the satellite and user geometry and the expected error characteristics: it is not affected by actual measurements. Therefore, this value is predictable.

1.3.3 Fault Detection and Exclusion (FDE)

Receiver Autonomous Integrity Monitoring (RAIM) perform consistency checks by using redundant pseudorange observations which provide integrity assurance for navigation systems. Fault Detection and exclusion (FDE) is a receiver processing scheme that autonomously provides integrity monitoring for the position solutions, using pseudorange observations. The FDE consists of two distinct parts: fault detection and fault exclusion. The fault detection part detects the presence of an unacceptably large position error for a given mode of flight. Upon the detection, fault exclusion follows and excludes the source of the unacceptably large position error, thereby allowing navigation to return to normal performance without an interruption in service.

Initially, RAIM only included the concept of fault detection, and later included the capability to isolate and exclude failed ranging source so that navigation can continue in the presence of the failure. At least 5 visible stars are required to implement fault detection and at least 6 to implement fault exclusion. The concepts of RAIM and FDE in this standard are equivalent.

Alert: For the definitions of missed alert, false alert, and time-to-alert, an alert is defined to be an indication that is provided by the BDS equipment when the positioning performance achieved by the equipment does not meet the integrity requirements. This alert is one of the conditions that would cause a navigation alert (ref.2.2.1.3.2).

Positioning Failure: A positioning failure is defined to occur whenever the difference between the true position and the indicated position exceeds the applicable horizontal protection level.

Note 1: HUL may be output after a positioning failure has been detected.

Missed Detection: A missed detection is defined to occur when a positioning failure is not detected.

Note 2: The term, missed detection, refers to internal processing of the FDE algorithm. It does not refer to an alert that is issued by the BDS equipment.

Time-To-Alert: Time-to-Alert is the maximum allowable elapsed time from the onset of a positioning failure until the equipment annunciates the alert.

Failed Exclusion (exclusion not possible): A failed exclusion is defined to occur when a true positioning failure is detected and the detection condition is not eliminated within the time-to-alert (from the onset of the positioning failure). A failed exclusion would cause a navigation alert.

Wrong Exclusion：A wrong exclusion is defined to occur when a detection occurs, and a positioning failure exists but is undetected after exclusion, resulting in a missed alert.

Missed Alert：Positioning failures that are not annunciated (as an alert) within the time-to-alert are defined to be missed alerts. Both missed detection and wrong exclusion conditions can cause missed alerts after the time-to-alert expires.

False Detection：A false detection is defined as the detection of a positioning failure when a positioning failure has not occurred. It is internal to the BDS equipment.

False Alert：A false alert is defined as the indication of a positioning failure when a positioning failure has not occurred (a result of false detection). A false alert would cause a navigation alert.

Note 3: The exclusion function may exclude a false detection internal to the BDS equipment, which does not contribute to the false alert rate (if an alert is not issued by the BDS equipment).

Availability of Detection：The detection function is defined to be available when the constellation of satellites provides a geometry for which the missed alert and false alert requirements can be met on all satellites being used for the applicable alert limit and time-to-alert. When the constellation is inadequate to meet these requirements, the fault detection function is defined to be unavailable. Thus the availability of detection for a specific location, time, constellation and horizontal alert limit (HAL) is defined to be:

$$Detection\ Availability\ (X, t, Const, HAL) = \prod_{i=1}^{N} D(i)$$

Where N= number of satellites being used by the BDS equipment

D(i)= 1, if Pr (detection given error in i^{th} satellite causing positioning error equal to HAL) ≥ the detection requirement and Pr (false alert) ≤ the false alert rate requirement.

0, otherwise.

Note 4: The detection function is expected to operate whenever sufficient measurement redundancy exists, regardless of whether or not it is "available" for the selected navigation mode by the definition above. Therefore, it may temporarily operate when the missed alert rate is greater than required for the appropriate alert limit (i.e., HPL>HAL), but the false alert rate must continue to meet requirements.

Availability of Exclusion: The exclusion function is defined to be available when the constellation of satellites provides a geometry for which the FDE algorithm can meet the failed exclusion requirement, and prevent the indication of a positioning failure or a loss of integrity monitoring function. Therefore, exclusion must occur before the duration of a positioning failure exceeds the time-to-alert, and the detection function as defined above must be available after exclusion. Note that for a given geometry and a given failed satellite, the success of the exclusion function to prevent an alert condition (duration of positioning failure exceeds time-to-alert) may be probabilistic. For example: given a particular exclusion algorithm, a satellite geometry, and a failed satellite, the algorithm could have a 99% probability of successfully preventing a warning condition. However, the exclusion function is only defined to be available if the probability of excluding a satellite and preventing an alert (given a satellite failure has occurred and has been detected) satisfies the failed exclusion requirement. Thus the availability of exclusion for a specific location, time, constellation and HAL is defined to be:

$$Exclusion\ Availability\ (X, t, Const, HAL) = \prod_{i=1}^{N} E(i)$$

where N=the number of satellites being used by the GPS/WAAS equipment

E(i)= 1, if Pr (Failed exclusion) ≤ 10^{-3} and detection still available after exclusion, given ith satellite failed,

0, if Pr (Failed exclusion)> 10^{-3} or detection not available given i^{th} satellite failed.

Note that for a given geometry and navigation mode, the exclusion function is either available or unavailable.

Note 5: The fact that the definition of exclusion availability states that *detection is required to be available after exclusion occurs is only intended to be used as a comparison of algorithmic availability. There may be significant operational benefit gained by an algorithm that is designed such that it is capable of excluding even when detection is not available after exclusion. However, such an algorithm must still meet the missed alert (including wrong exclusion) requirement on a per failure basis. In other words, there must be a means of demonstrating that, when exclusion is attempted without subsequent detection, the equipment excludes the correct satellite with a probability of at least 0.999(a 0.001 probability of missed alert).*

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

The following general requirements shall be met by all equipment.

2.1.1 Airworthiness

Design and manufacture of the airborne equipment must provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 General Performance

The equipment must perform its intended function, as defined by the manufacturer.

2.1.3 Fire Resistance

Except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not significantly contribute to the propagation of fire, all materials used must be self-extinguishing.

2.1.4 Sensor Interfaces

The interfaces with others aircraft equipment must be design such that normal or abnormal BDS airborne equipment operation will not adversely affect other equipment operation. Conversely, normal or abnormal operation of other equipment shall not adversely affect BDS airborne equipment unless expressly permitted.

2.1.5 Effects of Test

The design of the equipment shall be such that the application of the specified test procedures shall not produce a condition detrimental to the performance of the equipment except as specifically allowed.

2.2 Functional and Performance Requirements

2.2.1 Equipment Functional Requirements

The equipment shall meet the following functional requirements.

2.2.1.1 Satellite Selection

2.2.1.1.1 Satellite Integrity Status

The equipment shall designate each satellite/signal as "Healthy", "Unhealthy" or "Edge Status" , as defined in this Section. (The latency of this designation must be consistent with the requirements of Sections 2.2.1.3.)

2.2.1.1.2 Satellite/Signal Unhealthy

a. The equipment shall identify the satellite/signal unhealthy status indicated by "Satellite Health Status (HS)", "Signal Integrity Identifier (SIF)" and "Message Integrity Identifier (DIF)" in BDS B-CNAV1 messages.

Signal-in-Space Status	Health Identification for Signal and Message Types		
	B1C-（B-CNAV1）		
	HS	SIF	DIF
Unhealthy	0 or 1 or 2 or 3	1	0 or 1
	1	0 or 1	0 or 1

b. If the SISAI, SISMAI and other values of the signal-in-space accuracy index exceeds a certain range, the equipment shall identify the unhealthy state of the signal. For details, please refer to the subsequent updated version of *Beidou Navigation Satellite System Signal-in Space Interface Control File Public Service Signal B1C (Version 1.0).*

The satellite / signal unhealthy status shall be changed only after the condition has cleared.

2.2.1.1.3 Satellite/Signal Edge Status

The equipment shall identify the satellite/signal edge status indicated by "Satellite Health Status (HS)", "Signal Integrity Identifier (SIF)" and "Message Integrity Identifier (DIF)" in BDS B-CNAV1 messages.

Signal-in Space Status	Health Identification for Signal and Message Types		
	B1C-（B-CNAV1）		
	HS	SIF	DIF
Edge	0	0	1
	2 or 3	0	0

2.2.1.1.4 Satellite/Signal Health

The equipment shall identify the satellite/signal health status indicated by "Satellite Health Status (HS)", "Signal Integrity Identifier (SIF)" and "Message Integrity Identifier (DIF)" in BDS B-CNAV1 messages.

Signal-in-Space Status	Health Identification for Signal and Message Types		
	B1C-（B-CNAV1）		
	HS	SIF	DIF
Healthy	0	0	0

2.2.1.1.5 Satellite Selection

The equipment shall provide the following capabilities：

a. The equipment shall automatically select satellites for use in the position solution computation and for integrity algorithm;

b. The equipment shall use the same set of satellites in the position solution and for integrity;

c. Range measurement from any satellites designated "Unhealthy" shall not be used in the positioning solution. Range measurement from any satellites designated "Edge Status" shall not be recommended;

d. When a change to the selected set of satellites is necessary (e.g. the FDE algorithm eliminates the faulty satellite), the equipment shall accomplish this change within the time-to-alert as specified in Section 2.2.1.2.2.

It is recommended that the equipment does not provide manual de-selection of satellites to avoid situations where the pilot incorrectly de-selects satellites or fails to re-select them. In a BDS environment, it is highly unlikely that the pilot is aware of a satellite failure that the BDS system has not flagged. If manual de-selection is implemented, the manufacturer shall address these issues.

Consideration should be given to:

a. annunciations to remind the pilot that satellites have been de-selected;

b. the capability to readily re-select satellites;

c. the appropriate training to ensure proper equipment operation;

d. the equipment shall clear all previous manual de-selections at power-up;

e. manual selection of satellites that have been designated satellite/signal "Unhealthy" shall be prohibited.

2.2.1.2 Integrity Requirements

2.2.1.2.1 General Alerting Requirements

The equipment shall have a Fault Detection and Exclusion (FDE) capability that uses redundant BDS ranging measurements to provide independent integrity monitoring. Regardless of any method used to ensure integrity, the integrity shall meet the general specifications given in Section 2.2.1.2.

2.2.1.2.2 FDE-Provided Integrity Monitoring

This equipment shall compute a Horizontal Protection Level (HPL) using a weighted FDE algorithm. The weight shall account for clock/ephemeris, ionospheric, tropospheric, and airborne contributions to range error. The specific value given in Appendix 5 Table Appendix 5-2a is used before the Beidou official announcement documents.

If the manufacturer chooses to use different weights for the position solution and HPL_{FD} then the manufacturer shall substantiate that HPL_{FD} bounds the horizontal position error with a conditional probability of 0.999.

BDS equipment manufacturers have the option of using any RAIM technology that uses BDS measurements and barometric-assisted verification of position output integrity. Air pressure assistance can effectively improve the availability of BDS in the en route stage. The RAIM function for barometric altitude assistance is optional in this standard.

The RAIM algorithm provided by BDS sensors shall meet the following requirements.

Table Appendix 1-1 BDS Location Integrity Performance Requirements

Phase of Flight	**Alert Limit**	**False Alert**	**Time-to-Alert**	**Missed Alert**	**Failed Exclusion**	**Availability of Detection**	**Availability of Exclusion**
En route	2.0 NM	3.33×10^{-7}/Sample	8s	0.001	0.001	99.95%	99.30%

Note:

a) The equipment shall alert within 8 seconds for FDE-provided integrity monitoring.

b) The probability of missed alert shall be less than or equal to 0.001 *for every geometry and every navigation mode, regardless of which satellite is causing the positioning failure.*

c) The probability of false alert shall be less than or equal to 3.33 x 10^{-7} *per sample.*

d) The probability of failed exclusion shall be less than or equal to 0.001 for every geometry and every navigation mode, regardless of which satellite is causing the positioning failure.

e) Within the scope of the BDS service defined in the Beidou navigation satellite system public service performance specification (Version 3.0), if the constellation and grid specified in Section 2.2.1.1 are used for evaluation, and the same star selection algorithm and cover angle are used, the satisfaction Under the above integrity requirements, the availability requirements in the table shall be met.

2.2.1.2.3 Step Detector

The equipment shall detect a pseudorange step greater than 700 meters on any satellite used in the position solution, including steps that cause loss of lock for less than 10 seconds.

A pseudorange step is defined to be a sudden changes in the measured distance to a satellite. A pseudorange step can be caused by:

a) A change in navigation data; or；

b) A sudden change in the code phase.

If a pseudorange step is detected for a satellite , that satellite shall be excluded from use in the navigation algorithm until its integrity can be verified through fault detection (RAIM).

The equipment shall falsely declare a pseudorange step less frequently than or equal to $3.33x10^{-7}$ per sample.

If the equipment is capable of recovering a satellite after a step error has been declared, the declaration of a pseudorange step shall only be cleared if it is verified through autonomous fault detection.

Note：The manufacturer is free to choose any method to detect step errors. However, any method used should properly take into account satellite movement and aircraft dynamics.

2.2.1.3 Alerts/Outputs

The equipment provides position output and integrity data output, in particular loss of integrity monitoring or navigation.

2.2.1.3.1 Protection Level

The equipment shall output the Horizontal Protection Level. The equipment shall indicate if the HPL cannot be calculated (insufficient number of "Healthy" satellites/ fault detection is not available).

Note 1: In addition to the HPL, the equipment may output the HUL.

Note 2: When no HPL can be calculated, integrity monitoring is not provided.

2.2.1.3.2 Navigation Alert

The equipment shall provide an indication or output of the loss of navigation capability within one second of the onset of any of the following conditions:

a. The absence of power (loss of function is an acceptable indicator);

b. Equipment malfunction or failure;

c. The presence of a condition lasting five seconds or more where there are an inadequate number of usable satellites to compute a position solution (i.e., no computed data);

d. The presence of a condition where fault detection detects a position failure that cannot be excluded within the 8 seconds time-to-alert.

The alert shall be returned to its normal state immediately upon termination of the responsible condition.

Note: These failure/status indications shall occur independently of any operator action.

2.2.2 2D Accuracy Requirements (95% probability)

The total of error contributions of the airborne equipment shall not exceed either error value. Since FTE factors are beyond the control of equipment manufacturer or installer, these error sources are not included in this section.

The horizontal radial position fixing error shall not exceed 27m, 95th percentile , when HDOP is normalized to 1.5. This requirement shall be met under the minimum signal conditions defined in Section 2.2.3.1 and the interference conditions defined in Appendix 6.

If a time output is provides, it shall be within 1 second of UTC.

2.2.3 Signal Processing Requirements

The equipment shall be designed to process the BDS signals and necessary data described in *BeiDou Navigation Satellite System Public Service Performance Specification (Version 3.0)* and *Beidou Navigation Satellite System Signal-in Space Interface Control File Public Service Signal B1C (Version 1.0),* under interference conditions described in Section 2.2.3.2 and under the minimum signal conditions defined in Section 2.2.3.1.

The equipment shall decode the ionospheric coefficients in the BDS message, and apply the ionospheric corrections described in the *Beidou Navigation Satellite System Signal-in Space Interface Control File Public Service Signal B1C (Version 1.0)*. A tropospheric correction shall also be applied.

BDS satellite navigation data shall be continuously decoded. Except for the "Unhealthy" information (as defined in Section 2.2.1.1.2), new clock and ephemeris data shall only be used when the data is verified by reception of a second message containing the same data with a broadcast IODE that matches the 8 least-significant bits of broadcast IODC.

Ionospheric data shall not be used until the data is verified by reception of a second message, potentially from a different satellite, containing the same data.

The equipment shall apply the satellite clock correction (including relativistic corrections) derived from the clock parameters in the navigation message after smoothing the pseudorange measurement. For satellite clock correction and relativistic correction, please refer to *Beidou Navigation Satellite System Signal-in Space Interface Control File Public Service Signal B1C (Version 1.0)*.

The equipment shall not mistake one BDS satellite for another (i.e., false locks) due to cross-correlation during acquisition or reacquisition.

2.2.3.1 Sensitivity and Dynamic Range

All antennas shall comply with the independent BDS airborne navigation antenna CTSO standard. To the extent non-standard antenna performance is used to define the BDS equipment requirements, that performance shall be validated in accordance with the tests and methods described in the CTSO standard for independent BDS airborne navigation antenna.

Throughout this section (and the test procedures), signal and interference power levels are specified at the input to the preamplifier unless otherwise stated.

If the equipment is compatible with the active antenna conforming to the standard of independent Beidou airborne navigation antenna, the equipment shall accommodate BDS signals with a minimum input signal power of -136 dBm and a maximum input signal power of -115.5 dBm (although acceptable acquisition and tracking performance may not be achievable throughout this entire range). The equipment shall have the capability of tracking BDS satellites with a minimum input signal power of -133.5 dBm in the presence of sky and antenna thermal noise density ($N_{sky,\ antenna}$) of -172.5 dBm/Hz and the Appendix 6 interference conditions.

If the equipment is compatible with the passive antenna conforming to the standard of independent Beidou airborne navigation antenna, the equipment shall accommodate BDS signals with a minimum signal-in-space power of -131 dBm and a maximum signal-in-space power of -119.5 dBm (although acceptable acquisition and tracking performance may not be achievable throughout this entire range). The equipment shall have the capability of tracking BDS satellites with a minimum signal-inspace power of -128.5 dBm in the presence of sky and antenna thermal noise density ($N_{sky,\ antenna}$) for a specific antenna and the Appendix 6 interference conditions.

2.2.3.2 Integrity in the Presence of Interference

The equipment shall satisfy the applicable integrity requirement within the time-to-alert for the output of misleading information in the presence of interfering signals higher in power than the values specified in Appendix 6. Under these extreme conditions, it is acceptable to output a navigation alert, but not to output misleading information.

The equipment shall autonomously return to steady state accuracy

(Provides integrity monitoring as specified in Section 2.2.1.2 under the disturbance conditions of Section 2.2.3.3, Section 2.2.3.1 and Appendix 6) within 5 minutes after the interference conditions return to those specified in Appendix 6 for initial acquisition.

2.2.3.3 Acquisition Time

2.2.3.3.1 Initial Acquisition Time

The equipment shall be capable of acquiring satellites and determining a position without any initialization information, including time, position and BDS almanac data.

The time from power application to first valid position fix shall be less than 5 minutes with 95% confidence given the following:

a) Latitude and longitude initialized within 60 nautical miles;

b) Time and date within 1 minute；

c) Valid almanac data and unobstructed satellite visibility；

d) Under interference conditions of Appendix 6；

e) Under the signal conditions defined in Section 2.2.3.1.

In this context, valid position fix means all of the following conditions are met：

a) The determined position meets the accuracy requirements of Section 2.2.2, and continues to meet the requirement after the first valid position fix；

b) Integrity monitoring is provided as defined in Section 2.2.1.2.1；

2.2.3.3.2 BDS Acquisition Time

After steady state accuracy has been established, i.e., at least one minute of accurate navigation, the equipment shall be capable of incorporating a new BDS satellite signal into the position within 62 seconds.

This requirement applies to a satellite with the minimum signal power in the presence of interfering signals described in Appendix 6, and assumes valid almanac data is available. Note: 48 seconds is required to ensure that a new ephemeris message is received twice, plus 14 seconds for Doppler and range bin search. The 62 seconds begins when a satellite becomes available.

2.2.3.3.3 Satellite Reacquisition Time

For satellite signal outages of 30 seconds or less when the remaining satellites provide a GDOP of 6 or less, the equipment shall reacquire the satellite within 20 seconds from the time the signal is reintroduced. This requirement applies to a satellite with the minimum signal power in the presence of interfering signals as described in Appendix 6.

2.2.3.4 Satellite Tracking Capacity

The equipment shall be capable of simultaneously tracking a minimum of 8 BDS satellites.

2.2.3.5 Dynamic Tracking

a. Normal maneuvers: When the aircraft returns to unaccelerated flight from normal maneuvers, the equipment shall meet the 2D accuracy requirements of Section 2.2.2 within 10 seconds for all phases of flight to the maximum ground speeds shown below. Normal maneuvers include 180-degree heading changes with horizontal acceleration up to and including 0.58g, turn up to and including 1.3 times standard rate (but not more than 0.58g), and vertical accelerations up to and including ±0.5g.

For the normal operation of the aircraft, the accuracy requirements, satellite acquisition time requirements and satellite reacquisition requirements shall be met.

Flight Phase	Maximum Ground Speed	Horizontal Acceleration	Vertical Acceleration	Total Impact Rate
En route	800 kt	0.58g	0.5g	0.25g/s

b. Abnormal Maneuvers: When the aircraft returns to unaccelerated flight from abnormal maneuvers, the equipment shall meet the 2D accuracy requirements of Section 2.2.2 within 60 seconds for all phases of flight, to the maximum ground speeds shown below. Abnormal maneuvers consist of horizontal accelerations up to and including 2g.

During abnormal maneuvers, the equipment shall not output misleading information.

When the aircraft returns to normal maneuvers from abnormal maneuvers, the equipment shall meet the steady-state reacquisition requirements.

During the abnormal maneuver period, loss-of-navigation capability and loss-of-integrity monitoring alerts and outputs shall function as required by Section 2.2.1.3.2.

Flight Phase	Maximum Ground Speed	Horizontal Acceleration	Vertical Acceleration	Total Impact Rate
En Route	800 kt	2g	1.5g	0.74g/s

The equipment shall meet the applicable BDS position integrity performance requirements of Table Appendix 1-1 within the specified times in paragraphs a. and b.

2.2.4 Position Output

The equipment shall determine a position for navigation.

This position shall represent the WGS-84 position of the aircraft antenna (or center of navigation) at the time of applicability.

The equipment shall output (via electronic data interface) “position output data.”

The “position output data” shall consist of at least the time, position, velocity, horizontal position figure of merit ($HFOM_P$), and HPL. For the minimum output of the equipment, please refer to the table below in Table Appendix 1-2.

Table Appendix 1-2 Minimum Output of the Equipment

Number	Parameter	Unit	Positive Direction	Scope**	Significant Digits	LSB resolution
1	GNSS Latitude*	Degree	Due South	±180	31	8.38E-8
2	GNSS Longitude *	Degree	Due East	±180	31	8.38E-8
3	Horizontal Quality Factor	NM	***	16	15	4.88E-4
4	Horizontal Protection Level	NM	***	16	15	4.88E-4
5	GNSS Altitude (MSL)	Ft	Upward	±131,072	20	0.125

Number	Parameter	Unit	Positive Direction	Scope**	Significant Digits	LSB resolution
6	Vertical Quality Factor	Ft	***	32,768	15	1.0
7	Vertical Protection Level	Ft	***	32,768	15	1.0
8	GNSS TTK	Degree	Clockwise	±180	15	0.0055
9	GNSS Ground Speed	Knot	***	4,096	15	0.125
10	GNSS Vertical Speed	Ft/cent	Upward	±32,768	15	1.0
11	Time (UTC, UTC Fine)	Second	***	86,400	31	61.035μs
12	Date	Day/Month/Year	***	N/A	6	1 day
13	GNSS Altitude****	Ft	Upward	±131,072	20	0.125

* When both the longitude and latitude of a location are invalid, both are set to -180E

** When there is no value or the value is invalid, the default value is "1"

*** Always positive

**** GNSS Altitude refers to geodetic ellipsoid height.

2.2.4.1 Position Output Data Update Rate

The minimum update rate of position output data shall be once per second.

2.2.4.2 Position Output Data Latency

The latency of the position, velocity, and $HFOM_P$ output, defined as the interval between the time of the measurement and the time of applicability of the position and velocity, shall be less than or equal to 500 milliseconds.

2.2.4.3 Position Solution

The equipment shall use a weighted position solution.

2.2.4.4 Smoothing

Manufacturers should consider implementing carrier smoothing. If carrier smoothing is implemented, the smoothing filter output shall achieve an error less than 0.25 m within 200 seconds after initialization in the presence of a code-carrier divergence rate of up to 0.018 m/s relative to the steady-state response of the following filter:

$$P_{proj}=P_{n-1}+\frac{\lambda}{2\pi}(\emptyset_n-\emptyset_{n-1})$$

$$P_n=\alpha\rho_n+(1-\alpha)P_{proj}$$

where

P_n is the carrier-smoothed pseudorange in meters,

P_{n-1} is the previous carrier-smoothed pseudorange in meters,

P_{proj} is the projected pseudorange in meters,

ρ_n is the raw pseudorange measurement in meters (code loop carrier driven, 1st order or higher and with a one sided noise bandwidth greater than or equal to 0.125 Hz),

λ is the wavelength in meters,

ϕ_n is the accumulated carrier phase measurement in radians,

ϕ_{n-1} is the previous accumulated carrier phase measurement in radians, and

α is the filter weighting function (a unit less parameter), equal to the sample interval in seconds divided by the time constant of 100 seconds.

Note 1: The difference between the steady-state response of the smoothing filter implemented in the equipment and the steady-state *response of the filter defined above is included in the accuracy requirements.*

Note 2: The code-carrier divergence rate is assumed to be a Normal distribution with zero mean and a standard deviation of 0.012 m/s. Steady-state operation is defined to be following 360 seconds of continuous operation of the smoothing filter.

Note 3: One acceptable implementation of the airborne smoothing filter is the filter specified above. Smoothing can be done in parallel with other acquisition processes, making the smoothed pseudoranges available as quickly as possible.

2.2.4.4.1 Smoothing Pseudorange Accuracy

This requirement only applies to manufacturers that elect to perform carrier smoothing. The RMS of the total steady-state equipment contribution to the error in the corrected pseudorange for a BDS satellite at the minimum signal level shall be ≤ 0.36 meters.

2.2.4.5 Velocity Accuracy

The equipment's horizontal velocity output shall have an error that is less than 10 m/s, (95th percentile), when the HDOP is normalized to 1.5. This requirement shall be met under the minimum signal conditions defined in Appendix 6.

2.3 Equipment Performance-Environment Conditions

The environmental tests and performance requirements of this equipment are carried out with reference to Appendix 3.

2.4 Equipment Test Procedures

2.4.1 Definition of Terms and Conditions of Tests

The following definitions of terms and conditions of tests are applicable to the equipment tests specified herein:

a. Power Input Voltage

Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage ±2 percent. The input voltage shall be measured at the input terminals of the equipment under test.

b. Power Input Frequency

(1) In the case of equipment designed for operation from an ac power source of essentially constant frequency (e.g.,400 Hz), the input frequency shall be adjusted to design frequency ±2 percent.

(2) In the case of equipment designed for operation from an ac power source of variable frequency (e.g.,300 to 1000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within five percent of a selected frequency and within the range for which the equipment is designed.

c. Standard Test Signals and Simulator Requirements

(1) The satellite signal simulator should be operated in accordance with the *BDS Signal-in-Space Service Performance (Version 3.0)*, *BDS System Signal in Space Interface Control File Public Service Signal B1C*

(Version 1.0) and other standards.

(2) Unless otherwise specified, all BDS signals will not indicate UNHEALTHY, erroneous, failed, abnormal, or marginal conditions. The signals will contain ranging errors as calculated by approved models of the troposphere, ionosphere, satellite clock, and satellite ephemeris.

(3) The broadband noise used to simulate sky and antenna thermal noise density ($N_{sky,\ antenna}$), GNSS test noise ($I_{GNSS,\ Test}$) and external interference ($I_{Ext,\ Test}$) shall have a bandwidth greater than the RF bandwidth of the equipment under test. The CWI interference generator shall be accurate to within 1 kHz.

(4) The test signal supplied to the device under test, unless otherwise specified, shall state the preamplifier gain.

(5) For interference tests conducted with all satellites at maximum power, the test signals presented to the equipment under test shall be the maximum input signal at the receiver port accounting for the maximum preamplifier gain and minimum fixed loss between the antenna port and the receiver port.

(6) The test setup must provide the total specified broadband noise at the input to the test amplifier. This total noise comes from the simulator, a noise generator (as appropriate), and the test amplifier. The simulator noise ($I_{Simulator}$) includes all noise generated by the test equipment up to the input to the test amplifier. The test amplifier noise figure is NF_{Amp}, and

broadband noise from the noise generator is I_{NG}.

d. Adjustment of Equipment

The circuits of the equipment under test shall be aligned and adjusted in accordance with the manufacturer’s recommended practices prior to the application of the specified tests. The CWI interference generator may be adjusted within ±10Hz of the frequencies indicated to obtain the proper synchronous/nonsynchronous relationship.

e. Test Instrument Precautions

Due precautions shall be taken during the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.

f. Ambient Conditions

Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure and humidity. However, the room temperature shall be not lower than 10 degrees Celsius.

g. Warm-up

Unless otherwise specified, all tests shall be conducted after the manufacturer’s specified warm-up period.

h. Connected Loads

Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance values for which it is designed.

2.4.2 Test Procedures

Table Appendix 1-3 indicates the direct correspondence between the requirements of Section 2.2 and the tests of this section.

The basic composition of the test equipment required to perform these tests is in Figure Appendix 1-1.

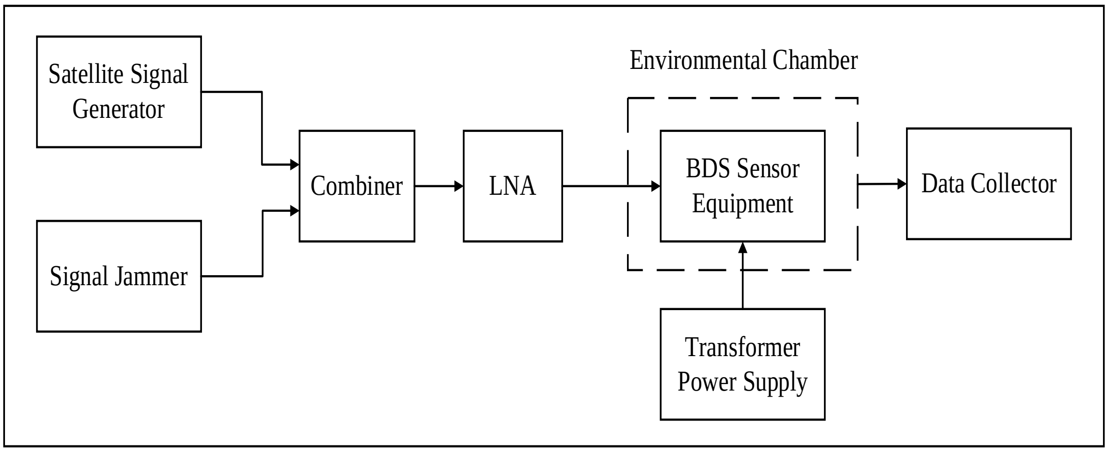

Figure Appendix 1-1 Reference Test Setup

Table Appendix 1-3 Test Level Reference Table

Requirements Section	**Subject**	**Test Section**
2.2.1.1	Satellite Selection	2.4.2.1
2.2.1.2	Integrity Requirements	2.4.2.2 2.4.2.7
2.2.2	2D Accuracy Requirements（95% Probability）	2.4.2.6
2.2.3.1	Sensitivity and Dynamic Range	2.4.2.3 2.4.2.4 2.4.2.8
2.2.3.2	Integrity in the Presence of Interference	2.4.2.5
2.2.3.3.1	Initial Acquisition Time	2.4.2.3
2.2.3.3.3	Satellite Reacquisition Time	2.4.2.4
2.2.3.5	Dynamic Tracking	2.4.2.8

2.4.2.1 Satellite Selection and Indication

Connect the equipment as shown in Figure Appendix 1-1. Use the simulator to generate the following geolocations

Number	Location	Latitude	Longitude
1	Oman	20°N	56°E
2	Port Louis	20°S	57°E
3	Kashi	39°N	76°E
4	Amsterdam Island	38°S	77°E
5	Golmud	34°N	92°E
6	Cocos Islands	12°S	97°E
7	Bose	23°N	106°E
8	Qingdao	36°N	120°E
9	Kendari	4°S	122°E
10	Fuyuan	48°N	134°E
11	Udnada Tower	27°S	135°E
12	Devonport	41°S	146°E
13	Etoro Island	45°N	149°E
14	Ust-Kamchask	56°N	162°E
15	Noumea	22°S	166°E
16	North Island	39°S	176°E
17	St. Johns	49°N	52°W
18	London	52°N	0°W
19	Buenos Aires	30° S	58° W
20	Ecuador	3° S	80° W
21	Los Angeles	34° N	118°W
22	Pacific Centre	5° S	135°W
23	North Alaska	70°N	150°W
24	Cape Verde	35°S	18°E

The set time is December 31, 2020 00:00:00. Refer to the orbital parameters in Appendix 7 to initiate a scenario using the BDS simulator. Using the mask angle on the BDS simulator as implemented in the equipment, the equipment under test shall select those satellites which are being simulated.

Make sure that the satellite is not selected when the simulated satellite message is:

a. When the “DIF” of 1 bit indicates that the error of the message parameters broadcast by the space signal exceeds the broadcast SISA value;

b. Signal in Space Accuracy Index SISAI, SISMAI and other values out of range;

Note: Manufacturers may choose not to automatically flag in this case; if so, the manufacturer must demonstrate validity of integrity monitoring with such a condition.

c. Health Status

When “HS” in 2bit of CNAV1 (B1C) message indicates that the whole star is unhealthy;

When 1bit “SIF” indicates that the signal is abnormal.

2.4.2.2 Step Detector Test

The step detector is tested under four scenarios. If the manufacturer can show by inspection that its equipment’s step detection mechanism is insensitive to the type of step (a change in navigation data or a sudden change in code phase), only one type of step need be tested. Typical satellite signal power may be used during these tests.

2.4.2.2.1 Verification of Step Detector Operation Without Exclusion Capability

Simulate a satellite scenario as follows:

1) Only five satellites in view and used in the positioning solution.

After the equipment reaches steady-state operation (i.e., navigates with integrity using all of the applied satellite signals), simulate a 750 meter step error on the hardest-to-detect satellite being used in the position solution by changing the navigation message. Repeat the test with a step change in code phase to simulate the 750 meter step error.

In order to pass, the equipment must do the following:

2) The satellite with the step error should be removed from the positioning solution within 10 seconds of introducing the pseudorange step;

3) The positioning error is not to exceed 200 meters throughout the entire test; and,

4) The HPL will be unavailable and the loss of integrity monitoring will be indicated.

Note: When a step is introduced by changing the broadcast ephemeris data, the pseudorange step does not occur until after receipt of a second set of the broadcast ephemeris (per Section 2.2.3).

2.4.2.2.2 Verification of No Interference with Fault Detection Algorithm

Simulate a satellite scenario as follows:

1) Only five satellites in view and used in the positioning solution; and,

2) HPL less than 0.3 NM.

After the equipment reaches steady-state operation, simulate a ramp error in the hardest-to-detect satellite being used in the position solution (10 meters/second).

In order to pass, the equipment must do the following:

1) At no time is there to be an exclusion of any satellite; and,

2) The FD algorithm shall indicate a positioning failure within the time-to-alert after the onset of the positioning failure;

2.4.2.2.3 Verification of Step Detector Operation with Exclusion Capability

Simulate a satellite scenario as follows:

1) Six or more satellites in view and used in the positioning solution; and

2) Detection and exclusion capability are available for an alert limit of 0.3 NM.

After the equipment reaches steady-state operation (i.e. navigates with integrity using all of the applied satellite signals), simulate a 750 meter step error on the hardest-to-detect satellite being used in the position solution by changing the navigation message. Repeat the test with a step change in code phase to simulate the 750 meter step error. To pass, the equipment must do the following:

1) The satellite with the step error shall be removed from the position solution within 10 seconds of introducing the step error;

2) The positioning error is not to exceed 200 meters throughout the

entire test, before and after the introduction of the step error; and

3) HPL will change.

Note: When a step is introduced by changing the broadcast ephemeris data, the pseudorange step does not occur until after receipt of a second set of the broadcast ephemeris (Section 2.2.3).

2.4.2.2.4 Verification of No Interference with Exclusion of the FDE Algorithm

Simulate a satellite scenario as follows:

1) Six or more satellites in view and used in the positioning solution; and,

2) Detection and exclusion capability are available for an alert limit of 0.3 NM.

After the equipment reaches steady-state operation, simulate a ramp error in the hardest-to-detect satellite being used in the position solution (10 meters/second).

In order to pass, the equipment must do the following:

1) The exclusion function should operate normally, eliminating the error as a positioning failure develops.

2.4.2.3 Initial Acquisition Test Procedures

2.4.2.3.1 Simulator and Interference Conditions

The tests to verify initial acquisition performance shall be run for each of the BDS signal generator (simulator) scenarios described below. It is not intended to verify the accuracy of the atmospheric corrections; these corrections need not be included in the test.

Scenario #1: Initial Acquisition Time Test

1) Exactly 5 BDS satellites with B1C code only.

2) Broadband GNSS test noise ($I_{GNSS,\ Test}$) of spectral density equal to -172.7 dBm/Hz at the antenna port (the contribution of simulated satellites has been removed for the specified noise density).

3) Broadband external interference ($I_{Ext,\ Test}$) of spectral density equal to -176.5 dBm/Hz at the antenna port.

4) Thermal noise contribution from the sky and from the antenna (See $N_{sky,\ antenna}$ in 2.2.3.1)

5) One satellite at maximum power (including maximum combined satellite and aircraft antenna gain), one satellite at minimum power (including minimum antenna gain), and other satellites 3 dB above the one satellite at minimum power (See 2.2.3.1)

6) Platform dynamics: Constant velocity of 800 kt beginning at 5,000 ft (MSL) and performing a 3° climb.

The test to verify initial acquisition performance after abnormal interference shall be run for the BDS signal generator (simulator) scenario described below:

Scenario #2: Initial Acquisition Time after abnormal interference Test

1) Exactly 5 BDS satellites with B1C code only.

2) Broadband GNSS test noise ($I_{GNSS, Test}$) of spectral density equal to -172.7dBm/Hz at the antenna port (the contribution of simulated satellites has been removed for the specified noise density).

3) Broadband external interference ($I_{Ext, Test}$) of spectral density equal to -176.5dBm/Hz at the antenna port.

4) Thermal noise contribution from the sky and from the antenna (See $N_{sky, antenna}$ in 2.2.3.1)

5) One satellite at maximum power (including maximum combined satellite and aircraft antenna gain), one satellite at minimum power (including minimum antenna gain), and other satellites 3 dB above the one satellite at minimum power (See 2.2.3.1).

6) Platform dynamics: Constant velocity of 800 kt and constant altitude.

The GNSS and external interference is to be applied to the receiver before it is powered on or the simulator is engaged.

2.4.2.3.2 Test Procedures (Initial Acquisition)

Scenario #1

1) The broadband GNSS test noise, the broadband external interference noise, and $N_{sky, antenna}$ shall be simulated.

2) The simulator scenario shall be engaged and the satellites RF shall be turned on.

3) The airborne equipment shall be powered and initialized to a position with total radial error equal to 60 nautical miles, and one minute (60 seconds) of error in time with respect to the starting position and time reference in the simulator. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting these tests.

4) The time to first valid position fix (TTFF), defined as the time from when the equipment is powered on until the first valid position (with integrity, i.e. HPL is available) is output, shall be observed. Integrity shall be provided by the sensor's FDE algorithm. Along with the TTFF, at least the next 60 seconds of continuous position fixes (a minimum of 60 data points) after the initial fix shall also be recorded in order to verify the accuracy requirement.

5) Precise ephemeris shall be purged or rendered invalid at the end of each acquisition attempt.

6) Go to Step 2 and repeat as required.

2.4.2.3.3 Pass/Fail Determination

The accuracy statistic that will be compared with the 15 m (95%) horizontal accuracy requirement stated in section 2.2.2 shall be computed using the 2drms formula shown below.

$$2\text{drms}=2\sqrt{\frac{\sum_{i=1}^{N}\left(\frac{1.5d_i}{HDOP_i}\right)^2}{N}}$$

Where:

2drms= Twice the distance, root-mean-square

d_i= Instantaneous 2-D horizontal position error (meters)

N= Number of points considered

$HDOP_i$= Instantaneous Horizontal Dilution of Precision

The use of the 2drms formula provides a conservative estimate of the 95% error and effectively weights large position errors that may be caused by unwanted interference.

A failure by the sensor to produce a position output after 5 minutes indicates a failure mode, and results in declaring the test a failure.

Scaling the instantaneous 2-dimensional position error (d_i) by $1.5/HDOP_i$ provides a means of normalizing the tests to a constant HDOP = 1.5 and accounts for fluctuations in the satellite coverage due to changing geometries. $HDOP_i$ may be obtained from the receiver under test or calculated separately. Only those satellites used in the position solution shall be included in the $HDOP_i$ calculation. The manufacturer shall demonstrate the validity of the values chosen for $HDOP_i$.

To determine the initial acquisition pass/fail criteria, consider a single trial where the sensor under test provides a valid position fix within the required time (5 minutes) and maintains the required accuracy (15 m, 95%) for at least the next 60 seconds. This sensor is considered to have passed one (1) trial. Table Appendix 1-4 shows the total test disposition and represents a quit-while-ahead testing approach designed to keep testing times at a reasonable length.

Table Appendix 1-4 GRADUATED SAMPLING PASS/FAIL CRITERIA

Trials	Cumulative Failures within Specified Time	Test Disposition
First Ten (10) Trials	Zero（0） One（1） Two（2）or More	Pass Run Ten（10）More Fail
Second Ten (10) Trials	Zero（0） One（1）or Two（2） Three（3）or More	Pass Run Ten（10）More Fail
Third Ten (10) Trials	Zero（0） One（1）or More	Pass Fail

For example, if no failures occur in the first ten trials, success for that simulator and interference case would be declared and the current test terminated. A single failure in the first set of ten trials necessitates running the next set of ten trials. Two or more failures during the first ten trials indicate that the sensor has failed that particular test, and so on.

2.4.2.3.4 Test Procedures (Initial Acquisition After Abnormal Interference)

（Scenario #2）

The abnormal CW interference frequency is at 1575.42 MHz and the power level is selected to ensure that no BDS satellites can be tracked at that power. The test procedure is the same as the initial acquisition test, with the following exceptions:

1) Before the equipment has output a valid position for one minute, the signal power may be set to a higher level, or, the broadband noise to a lower level to facilitate acquisition.

2) After the equipment has output a valid position for one minute, apply the abnormal CW interference. Remove the abnormal interference after 1 minute in the first trial, 2 minutes in the second trial, and so on up to 10 minutes in the tenth trial.

3) The time to first valid position fix (TTFF) for this test is defined as the time from when the abnormal CW interference is removed until the first valid position (with integrity, i.e. HPL is available) is output.

4) When reinitializing between trials, it is not necessary to purge the precise ephemeris data.

2.4.2.4 Satellite Reacquisition Time Test

2.4.2.4.1 Simulator and Interference Conditions

The tests to verify reacquisition performance shall be run for each of the BDS signal generator (simulator) scenarios described below:

Steady-State Reacquisition Time Test (BDS B1C code)

1) Broadband GNSS test noise ($I_{GNSS,\ Test}$) of spectral density equal to -172.4 dBm/Hz at the antenna port (the contribution of simulated satellites has been removed for the specified noise density).

2) Thermal noise contribution from the sky and from the antenna (See $N_{sky,\ antenna}$ in 2.2.3.1)

3) Broadband external interference noise ($I_{Ext,\ Test}$) of spectral density equal to -170.5 dBm/Hz at the antenna port.

4) Platform dynamics: Constant velocity of 800 kt beginning at 5,000

ft (MSL) and performing a 3° climb.

5) Any number of BDS satellites at any power until the sensor reaches steady state navigation.

6) Then one satellite at maximum power (including maximum combined satellite and aircraft antenna gain), one satellite at minimum power (including minimum antenna gain), and other satellites 3 dB above the one satellite at minimum power (See 2.2.3.1).

7) Then, turn off the minimum power satellite to retain exactly 4 BDS satellites providing a GDOP of 6 or less, preparing to reacquire the lost BDS satellite, which is just above the mask angle and whose RF state (on or off) shall be controlled by the simulator.

8) Finally, the signal from the fifth BDS satellite to be acquired is turned on at minimum power.

2.4.2.4.2 Test Procedures

1) The broadband GNSS test noise, the broadband external interference noise, and $N_{sky, antenna}$ shall be simulated.

2) The simulator scenario shall be engaged and the satellites RF shall be turned on.

3) The airborne equipment shall be powered. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting these tests

4) The sensor shall be allowed to reach steady state accuracy before

the satellite to be reacquired is cycled off and on. Once in steady state navigation, the simulated satellites and the broadband noise shall be set to the appropriate steady state power levels.

5) The reacquisition satellite to be tested should be removed from the sensor (with the RF switch of the satellite to be reacquired turned off on the GNSS signal simulator), at least until the sensor's signal to this satellite goes into a loss-of-lock state and the satellite is removed from the positioning solution. Removed in the calculation, then reapplied to the sensor within 30 seconds (returning the RF switch for this satellite).

6) The reacquisition time, or time to satellite inclusion, defined as the time from when the satellite under test is reapplied to the sensor until the first valid position which includes that satellite is output, shall be observed. In addition, at least the next 60 seconds of position fixes (sampled at the minimum of once per second) after the inclusion of the reacquired satellite, shall also be recorded in order to verify the 15 m (95%) requirement.

7) Reset the scenario (including signal and noise power levels), go to Step 2 and repeat as required.

2.4.2.4.3 Pass/Fail Determination

The accuracy statistic shall be computed using the 2drms formula as shown in Section 2.4.2.3.

To determine the reacquisition time pass/fail criteria, the graduated sampling pass/fail criteria of Table Appendix 1-4 shall be used.

A single trial success occurs when the sensor under test includes the reacquired satellite into the position solution within the required time (20 seconds) and maintains the required accuracy, 15 m (95%), for the following 60 seconds.

The statistical justification for the reacquisition time test follows that for initial acquisition and can be found Appendix M of DO-316.

2.4.2.5 Interference Rejection Test

2.4.2.5.1 Simulator and Interference Conditions

These tests are intended to verify the performance of the sensor in the presence of inband continuous-wave interference conditions at and above the levels of Appendix 6. Tests shall be run for the BDS signal generator (simulator) scenario described below. The interference test does not have to verify the accuracy of atmospheric corrections, and these corrections do not need to be included in this test.

The simulation and Interference conditions shall conform to the following two requirements:

1) Simulated BDS RF (received power) of the PRN 24 shall be at the minimum power level of the device (as described in Section 2.2.3.1). Other satellites should be at high power levels to minimize the effect of interference on their pseudoranges.

2) The initial CW power shall be -120.5 dBm (may be reduced during initial acquisition). The I/S ratio will be varied according to the test

procedures. The exact frequency relationship must be maintained throughout the test. The scenario shall include PRN 24 because it is used in the definition of the CWI frequency.

Note: This evaluation method is based on the assumption that a weighted least-squares position algorithm is implemented, and that the baseline integrity algorithms are used. If a different form of positioning or integrity method is used, this evaluation method may not be appropriate.

2.4.2.5.2 Test Procedures

1) The CW interference to be applied shall be turned on and connected to the sensor. Note that the power of the CW interference during initial acquisition is lower than that for steady-state operation. Broadband external interference and GNSS test noise do not need to be simulated for this test.

2) The simulator scenario shall be engaged and the satellites RF shall be turned on.

3) The airborne equipment shall be powered and initialized. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting these tests.

4) The sensor shall be allowed to reach steady state. When the sensor has reached steady state, the power of the CW interference shall be adjusted to -120.5 dBm.

5) The CW interference power shall be maintained until the accuracy

has reached steady-state. Pseudorange measurements and pseudorange validity indications (e.g., isolation bit) for all satellites shall be recorded during this interval.

6) The power of the CW interfering signal shall be increased by 1 dB and maintained for 200 seconds. Pseudorange measurements and pseudorange validity indications (e.g., isolation bit) for all satellites shall be recorded during this interval.

7) Go to Step 6 and repeat until PRN 24 has been excluded from the navigation solution. Increase the CW interfering signal another 3 dB and verify that PRN 24 is still excluded. It needs to be ensured that the elevation angle when PRN 24 is excluded is always greater than the satellite occlusion angle.

2.4.2.5.3 Pass/Fail Determination

For each sample when the PRN 24 pseudorange is declared valid, the following error criterion shall be evaluated:

$$Z_j \leq 5.33\frac{N_j - 1}{N_j}\sigma_{noise,PRN24,j}$$

Where：

$$Z_j = PR_{PRN24,j} - R_{PRN24,j} - (c\Delta t)_j$$

$$(c\Delta t)_j = \frac{1}{N_j}\sum_{i=1}^{N_j}\left(PR_{ij} - R_{ij}\right)$$

PR_{ij} = pseudo-range, channel i, time j

R_{ij} = true range, satellite i, time j (includes extrapolation)

N_j = number of satellites at time j

$\sigma_{noise,ij}$ = receiver output or equivalent, satellite i, time j (refer to Appendix J3 of DO-316)

If the error criterion is exceeded for more than the appropriate time to alert, the test fails.

2.4.2.6 Accuracy Tests

2.4.2.6.1 Measurement Accuracy Test

The purpose of the Accuracy Test is to validate that the equipment meets the accuracy requirements of Section 2.2.2 under the specified interference conditions. It is also intended to verify that the σ_{noise} used in the protection level equations is an appropriate bound on the residual errors allocated to the receiver tracking performance.

It is not intended to verify the accuracy of the atmospheric corrections; these corrections need not be included in the test.

Note: This evaluation method is based on the assumption that a least-squares position algorithm is implemented. If a different form of positioning is used, this evaluation method may not be appropriate.

The threshold for receiver pseudorange measurement accuracy is equal to 5 meters (σ_{air}) minus the error value for multipath effects (σ_{mp}) assigned by the manufacturer. Manufacturers need to determine the allocation between thermal noise and multipath error and adjust this threshold appropriately.

2.4.2.6.2 Simulator and Interference Conditions

The simulation and interference conditions shall conform to the following requirements:

1) For all test scenarios, the broadband GNSS test noise and $N_{sky, antenna}$ shall be simulated. There are three sets of interference test scenarios: broadband external interference noise, Continuous Wave Interference, and pulsed interference.

a) The broadband external interference noise ($I_{Ext, Test}$) has a spectral density equal to -170.5 dBm/Hz as seen at the antenna port.

b) The CW power and frequencies are listed in Table Appendix 1-5.

c) For the pulsed interference tests, a pulse modulated carrier at 1575.42 MHz with a signal bandwidth of 1 MHz, with peak carrier level of +10 dBm, pulse width of 125 usec, and duty cycle of 1% shall be used. This corresponds to an I/S ratio of +144 dB for BDS satellites.

2) The GNSS test noise depends on the number, power, and type of satellites simulated during the test.

The power spectral density of the total GNSS Noise (I_{GNSS}) is -171.9 dBm/Hz (See Section 2.3 of Appendix 6).

The effective noise power spectral density (I_{Test}) of the satellites present in the simulator scenario may be removed from the total GNSS Noise; to do so, the satellite equivalent power spectral density specified in

Table Appendix 1-5 (I_{BH}、I_{BL}、I_{SH}、I_{SL}) is removed for each satellite present. The number of maximum power BDS satellites is N_{GH}, the number of minimum power BDS satellites is N_{GL}, the number of maximum power SBAS satellites is N_{SH}, and the number of minimum power SBAS satellites is N_{SL}. The GNSS test noise is determined by removing I_{Test} from I_{GNSS} as follows:

$$I_{GNSS,Test} = 10log10[10^{\frac{171.9}{10}} - 10^{\frac{I_{Test}}{10}}]$$

Where:

$$I_{Test} = 10log10[(N_{BL})10^{\frac{I_{BL}}{10}} + (N_{BH})10^{\frac{I_{BH}}{10}} + (N_{SL})10^{\frac{I_{SL}}{10}} + (N_{SH})10^{\frac{I_{SH}}{10}}]$$

（I_{BH}、I_{BL}、I_{SH}、I_{SL} represents the power spectral density of the equivalent satellite respectively, see the table below）

Note: The indicated power levels (both signal and noise) are for the steady-state portion of the tests; power levels are set to the required values once steady state navigation has been achieved. Refer to Appendix M of DO-316 for an explanation of how I_{Test} is derived and examples of the computation of $I_{GNSS,\ Test}$ and how it may be applied.

3) Simulated BDS and SBAS RF shall be at the minimum power level for the equipment, except for the broadband external interference noise case that shall be tested at the maximum power level as well as the minimum power level.

For test cases that require the minimum power level, one BDS satellite shall be set to the maximum power level (including maximum transmit power and maximum combined satellite and aircraft antenna gain). For these cases the pseudorange samples of the satellite at maximum power are not used in the evaluation. The scenario shall include PRN 24 because it is used in the definition of the CWI frequency. For all conditions, during the portion of the test where accuracy is evaluated, at least two SBAS satellites signal shall be advertised.

Note 1: The steady-state accuracy test will include a total of nine cases (ten when installed on aircraft with SATCOM).

4) The total duration of each test case test shall be based upon sampling intervals required to obtain samples that are statistically independent. Independent samples collected during the initial acquisition and before steady-state operation are used for the validation of σ_{noise} overbounding. The samples collected prior to steady-state operation should not be used for the steady-state RMS accuracy evaluation and the steady-state evaluation of $\left(\sigma_{noise}^2[i]+\sigma_{divg}^2[i]\right)^{\frac{1}{2}}$.

Table Appendix 1-5 STEADY STATE ACCURACY TEST CWI VALUES

Frequency (MHz)	Power (dBm)	I/S(dB)
1525.0	-12.0	122.0
1555.42	-89.5	44.5
1575.42**	-120.5	13.5
1595.42	-89.5	44.5
1610.0	-30.0	104.0
1618.0	-12.0	122.0
1626.0***	8	142.0

*The CWI power is specified at the antenna port. The actual level used during testing is reduced by the minimum frequency selectivity of the active antenna adjusted for any filtering in the test set-up itself. When demonstrating compatibility with a minimum standard active antenna, the frequency selectivity is specified in Appendix 6.3 (derived from RTCA/DO-301). When using a passive antenna, the interference levels specified in Appendix 6.2.1 and the total frequency selectivity of the user equipment should be taken into account. When using a specific antenna, its minimum frequency selectivity can be used when determined in accordance with RTCA/DO-301.

** The CWI must be synchronized to the satellite signal provided. The exact frequency relationship must be maintained throughout the test.

*** Only Required for Aircraft with SATCOM

Note: Care should be taken when applying non-L1 CW frequencies so that the L1 CW and broadband specifications are not exceeded.

Table Appendix 1-6 SATELLITE EQUIPMENT POWER SPECTRAL DENSITY

Satellite Type	**Maximum Power Satellite**	**Minimum Power Satellite**
BDS	$I_{BH} = -183.5\ dBm/Hz$	$I_{BL} = -196.5\ dBm/Hz$
SBAS	$I_{SH} = -179.8\ dBm/Hz$	$I_{SL} = -198.3\ dBm/Hz$

Note: These values of equivalent power spectral density were computed using the same assumptions as were used to determine the total GNSS Noise in Appendix 6.

2.4.2.6.2.1 Test Procedures

1) The test unit is connected to the RF signal and interference source.

2) The simulator scenario shall be engaged and the satellites RF shall

be turned on.

3) The equipment under test shall be powered and initialized. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting these tests.

4) When the unit is navigating, the interference to be applied shall be applied to the equipment under test, and the power of the signal and interference shall be adjusted to the required level. Sampling should begin for each satellite immediately after it is included in the navigation solution for the σ_{noise} overbounding evaluation described in paragraph 8 below.

5) When steady-state accuracy is reached, data are recorded as follows:

6) Initially, 50 independent samples of pseudorange data are recorded at the required sampling interval (see note below).

Note: The sampling interval will be two times the integration interval used for carrier phase smoothing of pseudoranges. For example, if the integration interval used for carrier smoothing of the pseudoranges is 100 seconds, the sampling interval will be 200 seconds. If pseudorange measurements for ten satellites are collected per sampling interval, this results in 9 independent samples, as the equivalent of one measurement must be used to estimate the receiver clock bias $c\Delta t$ for this interval. The duration of the initial data collection period will then be approximately 18.5 minutes [computed as follows: (50 independent samples) × (1 sampling interval / 9 independent samples) × (200 seconds / 1 sampling *interval) × (1 minute / 60 seconds)]. If unsmoothed pseudoranges are used for this test the time interval between independent samples is typically 1 second.*

7) The normalized RMS range error statistic, RMS_PR, is computed according to the following formula, using all collected samples (including those prior to steady-state operation):

$$RMS\_PR(M) = \sqrt{\frac{\sum_{j=1}^{M}\left\{\sum_{i=1}^{N_j}\frac{Z_{ij}^2}{[\sigma_{norm,ij}^2 N_j]}\right\}}{M}}$$

Where：

$$Z_{ij} = PR_{ij} - R_{ij} - (c\Delta t)_j$$

$$(c\Delta t)_j = \frac{1}{N_j}\sum_{j=1}^{N_j}(PR_{ij} - R_{ij})$$

$$\sigma_{norm,ij}^2 = \frac{\left[(N_j - 1)^2\sigma_{noise,ij}^2 + \sum_{\substack{k=1\\k\neq i}}^{N_j}\sigma_{noise,kj}^2\right]}{N_j}$$

PR_{ij}= pseudo-range, channel I, time j

R_{ij}= true range, satellite i, time j (includes extrapolation)

N_j= number of satellites at time j

M= number of sampling intervals

$\sigma_{noise,ij}$ = satellite i， time j（refer to Appendix J.3 of DO-316）

Note 1: Interchannel biases on the simulator may impede the accuracy test specified herein. It may be necessary to determine this bias and inflate the test threshold based upon equipment calibration. If two receivers are *used to remove this bias (via double-differencing), the test must account for potential interchannel biases in the receivers themselves and cannot simply remove all bias components.*

Note 2: Since code-carrier divergence is not simulated in this test, the σ_{divg} *term is not used in this normalization. Validation of* σ_{divg} *should be accomplished by analysis.*

(Three performance indicators that need to be verified, and the corresponding criteria:)

8) Verification of σ_{noise} overbounding: The error statistic is compared to the 110% Pass Threshold of Table Appendix 1-7 based on the Number of Independent Samples (NIS), where NIS is given by:

$$NIS(M) = \sum_{j=1}^{M} (N_j - 1)$$

If RMS_PR is below the pass threshold, the result is a pass. If the RMS_PR is not below the pass threshold, additional data may be collected. In this case, the RMS_PR shall include the initial independent samples plus all additional data, and the formulas and pass criteria of this section (which apply for an arbitrary number of samples) shall be used.

Note: It is expected that the pass criteria will not be met with the initial data collection (only the initial acquisition and 50 steady-state operation independent samples due to the limited sample size). Development of the test criteria, and the associated pass probabilities are described in Appendix M of DO-316.

9) Steady-state value of $\left(\sigma_{noise}^2[i]+\sigma_{divg}^2[i]\right)^{\frac{1}{2}}$: Using only those samples collected during steady-state, the average $\left(\sigma_{noise}^2[i]+\sigma_{divg}^2[i]\right)^{\frac{1}{2}}$ output values for each satellite are compared to the requirements of J.3 of DO-316. The output values must be less than or equal to the required accuracy values (0.36m) for the designator of the equipment.

10) Verification of RMS accuracy: The steps defined in paragraph 6 and 7 are repeated using only those samples collected during steady-state operation and using the required RMS accuracy (section 2.2.2 minus any steady-state value of σ_{divg} and minus the manufacturer's allocation to multipath) instead of the output $\sigma_{noise, i, j}$ in the computation of $\sigma_{norm, i, j}$ The pass criteria defined in paragraph 8 applies.

$$\sigma_{required,ij}^2=\sigma_{air,ij}^2-\sigma_{divg,ij}^2-\sigma_{multipath,ij}^2$$

$$\sigma_{norm,ij}^2=\frac{\left[(N_j-1)^2\sigma_{required,ij}^2+\sum_{\substack{k=1\\k\neq i}}^{N_j}\sigma_{required,kj}^2\right]}{N_j}$$

Table Appendix 1-7 PASS THRESHOLD TABLE

NIS	110% Pass Threshold	125% Pass Threshold
25-50	N/A	1.084
50-75	0.954	1.137
75-100	0.981	1.159
100-150	0.998	1.172
150-200	1.017	1.187
200-300	1.028	1.196
300-400	1.042	1.206
400-500	1.050	1.212
500-750	1.055	1.216
750-1000	1.063	1.222
1000-1250	1.068	1.226
1250-1500	1.072	1.229
1500-2000	1.074	1.231
> 2000	1.078	1.233

Note 1: The 110% pass threshold yields a 10% probability of passing equipment with a true accuracy of 110% of the required accuracy. The 125% pass threshold yields an 80% probability of failing equipment with a true accuracy of 125% of the required accuracy.

Note 2: The requirements of section 2.2.2 include both thermal noise and multipath errors in the allocation to the airborne equipment. Manufacturers must allocate a portion of this requirement to the multipath errors that may occur as a result of the design choices. While it is not required to simulate multipath errors for this test, it is necessary to reduce the threshold used in the computation of $\sigma_{norm,\ i,\ j}$. *For example, a manufacturer that chooses to smooth the pseudoranges used in the position solution may expect to see a* $\sigma_{multipath}$ *less than or equal to 0.45 meters. The value used in the computation of* $\sigma_{norm,\ i,\ j}$ *would then be* $\sqrt{5^2 - 0.45^2} = 4.98m$. *(The multipath experienced by receivers that do not smooth pseudoranges for satellites at low elevations can be up to 10 times greater.)*

2.4.2.6.3 24-Hour Actual Satellite Accuracy Test

2.4.2.6.3.1 Test Procedure

The equipment shall be tested over a 24-hour period using actual (live) BDS satellites. The horizontal position errors shall be normalized by $1.1d_{major}$ as defined below. The RMS of the normalized errors is compared to the pass threshold in Table Appendix 1-7.

For the purpose of this test, d_{major} is defined as follows:

$$d_{major} = \sqrt{\frac{d_{east}^2 + d_{north}^2}{2} + \sqrt{\left(\frac{d_{east}^2 - d_{north}^2}{2}\right)^2 + d_{EN}^2}}$$

Where

$$\begin{bmatrix} d_{east}^2 & d_{EN} & d_{EU} & d_{ET} \\ d_{EN} & d_{north}^2 & d_{NU} & d_{NT} \\ d_{EU} & d_{NU} & d_U^2 & d_{UT} \\ d_{ET} & d_{NT} & d_{UT} & d_T^2 \end{bmatrix} = (G^T W G)^{-1}$$

The i[th] row of the geometry matrix G is defined as follows:

$\mathbf{G}_i = [-\cos El_i \sin Az_i, -\cos El_i \cos Az_i, -\sin El_i, 1]$

When positive azimuth is defined clockwise from north.

Note: The sign and coordinate frame convention used is different from the one adopted for GBAS in RTCA/DO-253 and for ICAO standards; however, the definitions of the G-matrix adopted by these standards are all mathematically equivalent.

$\mathbf{W} = \mathrm{diag}(w_1,\ldots,w_N)$ is the weighting matrix.

Acceptable values of the weights $w_i = 1/\sigma_i^2$ are defined in Appendix J, Section J.1 of DO-316, with the following two exceptions:

- The multipath contribution to $\sigma_{i,air}$ is replaced by a term representative of multipath error in the ground test environment.
- The ionospheric contribution to $\sigma_{i,\ UIRE}$ is replaced by a term representative of ionospheric error at the test location.

If alternate error model contributions are used, they shall be substantiated by data or analysis.

2.4.2.6.3.2 Pass/ Fail Criteria

Equipment shall be considered pass if accuracy and integrity requirements are maintained throughout the 24-hour test (i.e. the RMS condition is met and the error never exceeds the HPL).

2.4.2.7 Integrity Monitoring Test Procedures

The verification of the FDE algorithm for the equipment shall consist of four tests. The first test (Section 2.4.2.7.2) shall demonstrate that the FDE algorithm provides proper fault detection and fault exclusion availability, and will be performed off-line. The second test (Section 2.4.2.7.3) is an off-line test to verify that the missed alert and failed exclusion requirements are satisfied. The third test (Section 2.4.2.7.4) is an off-line test to verify the false alert rate. The final test (Section 2.4.2.7.5) is an on-line test to verify that the algorithm that is implemented in the equipment is identical to the algorithm used during the off-line tests. Note that the on-line test specifies several additional off-line scenarios for comparison to on-line results.

Note: The above four test methods are the recommended methods of this standard, and the applicant may use other test methods to verify the FDE algorithm.

2.4.2.7.1 General Test Conditions

2.4.2.7.1.1 Test Philosophy

These tests specify the procedures and pass/fail criteria for equipment demonstrating compliance with the FDE requirements in Section 2.2.1.2. With the exception of the first test for availability, the test is independent of the navigation mode and does not have to be repeated for different modes.

2.4.2.7.1.2 BDS Constellation

The BDS satellite constellation used in the simulations shall be the satellites constellation defined in Appendix 7. In all tests, the satellite selection algorithm and number of channels shall be the same as that used by the equipment. The mask angle shall be 5 degrees, regardless of the mask angle of the particular equipment under test.

2.4.2.7.1.3 Tool Qualification Considerations

The off-line FDE software used to test compliance with FDE requirements shall at least be compliant to RTCA/DO-178B/C or equivalent. The software shall be designed such that the implementations of the position solution, FDE and satellite selection algorithms are functionally identical in both the BDS equipment and the off-line software.

2.4.2.7.1.4 Test Repetition

If the equipment fails two successive tests defined in Section 2.4.2.7.3 or 2.4.2.7.4 with different sets of numbers for the random processes, the integrity algorithm must be modified to correct the problem before re-testing. Re-testing must be done for all FDE tests.

2.4.2.7.1.5 Protection Level/Alert Limit

In order to reduce the amount of test time, these tests are based upon the HPL_{FD} used internal to the equipment. By predicating these tests upon the HPL_{FD}, the navigation mode is irrelevant and the tests can be conducted only once. In addition, the satellite geometry should not be a dominant factor since the equipment is tested to the worst-case satellite. The off-line HPL_{FD} used for this test shall not include any additional margin that is a function of the navigation mode. For example, if the HPL_{FD} is 0.2 NM, but the equipment inflates this value to the approach (LNAV) HAL of 0.3 NM to improve the false alert rate, the equipment must be tested to a HPL_{FD} = 0.2 NM. Therefore, for the purposes of these tests a positioning failure is referenced to the HPL_{FD}, not the HAL. Similarly, the tests conducted when exclusion is available are referenced to the HEL_{FD}, not the HAL.

2.4.2.7.1.6 Time-to-Alert

These tests shall use the appropriate time-to-alert for the equipment under test. Recall that the total time-to-alert for the position output is 8 seconds, regardless of the value of HPL_{FD}.

The time-to-alert used in these tests shall accommodate the equipment latencies after fault detection and provides time to attempt exclusion before indicating the fault. For example, if a sensor has a 200 ms delay in issuing a navigation alert due to a positioning failure, then the time-to-alert for these tests would be (8 seconds - 0.2 seconds) = 7.8 seconds.

2.4.2.7.2 Availability Tests

The off-line test described in this paragraph shall be used to demonstrate compliance with the availability requirements of Section 2.2.1.2. Availability of fault detection and fault exclusion shall be determined for each of the space-time points in the following analysis grid sampled every 5 minutes for 12 hours from 00:00:00 to 12:00:00 UTC (144 time points). The error model described below:

Note: Because section 2.4.2.7.5 requires identical performance between on-line and off-line algorithms; and, section 2.4.2.7.2 requires using specific weights to compute HPL, this implies user equipment should use the weights below to compute HPL.

Analysis grid: Points are sampled every three degrees in latitude from zero to ninety degrees north. Each latitude circle will have points separated evenly in longitude, defined as:

$$long.step = \frac{360}{ROUND(\frac{360}{\min(3\deg rees/\cos(latitude),360)})}$$

This grid yields 2353 points.

Note that the total number of space-time points is 2353*144 = 338,832 points.

The availability of fault detection for each space-time point shall be determined as defined in Section 1.3.3（BDS 216）. The availability of detection（BDS 217）shall be determined for the en route HALs.

Similarly, the availability of exclusion shall be calculated for each space-time point as defined in Section 1.3.3. The availability of exclusion shall be determined for the en route HALs.

The availability calculations for each space-time point shall be based upon the same set of satellites that would be used by the equipment. This requires that the satellite selection algorithm be used to select the satellites for use in the FDE algorithm. In addition, the mask angle shall be 5 degrees.

The total number of space-time points for which the detection function is available shall be determined (N_d). The total number of space-time points for which the exclusion function is available shall be determined (N_a). The availability is then determined as:

$Availability\ of\ Detection = N_d / 338832$

$Availability\ of\ Exclusion = N_a / 338832$

If additional augmentations are used to improve system availability, the effects of those augmentations must be completely simulated. In particular, equipment logic that affects when the augmentation is applied shall be simulated. For augmentations that do not result in predictable HPL_{FD}'s for a given geometry, location, and time, the statistical nature of the HPL_{FD} must be taken into consideration and the total number of samples taken increased accordingly.

2.4.2.7.3 Off-Line FDE Tests

2.4.2.7.3.1 Off-Line Test Setup

For BDS signals, the noise models specified above shall apply to the pseudo range measurements. The effect of equipment tracking-loop noise shall be modeled with a single white noise term with an RMS value representative of the equipment under test at the minimum carrier-to-noise ratio (C/N_0). Such noise shall be generated as Gaussian white sequence with samples that are uncorrelated in time.

The sampling interval used in the simulation tests shall not exceed 1 second. A BDS satellite malfunction shall be simulated as a ramp error in measured pseudorange with a slope of 5 m/s.

Different noise samples shall be used for each satellite being used in the FDE algorithm, and new sets of noise samples are to be generated and used for each run.

During all runs in the off-line simulation tests, satellite velocities are to be set to zero, and the satellite positions are to be frozen at the values for the selected geometry. This ensures that HPL will not change during the run.

All tests in this section are based upon the assumption that all satellite range measurements have identical error models, the equipment shall de-weight each range measurement based upon the expected error residual. In this case, the equipment must demonstrate that it satisfies all FDE requirements with a combination of expected error characteristics.

2.4.2.7.3.2 Selection of Geometries

The space-time points analyzed under Section 2.4.2.7.2 shall be reviewed to yield the following sets of points. If the geometries cannot be found for any set, deselect satellites in order to find acceptable geometries.

Set 1: Twenty geometries shall be selected to provide an approximately uniform range of HPL_{FD} from 0.1 NM to the maximum HAL supported by the equipment (e.g., 4 NM). Note that only the missed alert and false alert probabilities are required to be satisfied under this condition.

Set 2: Twenty geometries shall be selected to provide an approximately uniform range of HEL_{FD} from 0.1 NM to the maximum HAL supported by the equipment (e.g., 4 NM). Note that all requirements (missed alert, false alert, failed exclusion) must be satisfied for this set.

2.4.2.7.3.3 Test Procedure

One of the most difficult issues to test is the integration of the exclusion and detection functions. In particular, the exclusion requirements state that the equipment must exclude the failure prior to the radial error becoming unacceptable and without alerting the user.

Because the equipment that does not know the HAL, the decision of when to indicate a failure to the user can, in this situation, be made by the navigation management unit (typically a flight management system). Therefore, it is acceptable for the equipment to indicate an alert as soon as a detection occurs together with an output of the HUL. In this case, the navigation management unit must decide when the error becomes unacceptable and must be annunciated.

The integrated system (receiver and the navigation management unit) would be expected to withhold indication of the failure until it becomes unacceptable if exclusion is available.

In addition to the data recorded specifically for this test, the position trace and alert status shall be recorded for several runs in support of the on-line test procedures. See Section 2.4.2.7.5 for a discussion of which runs should be retained.

For each of the 40 geometries selected above, a ramp-type failure with a velocity of 5 m/s shall be introduced. For Set 1, the failure shall be introduced in the most difficult to detect satellite. For Set 2, the failure shall be introduced in the most difficult to exclude satellite. A Monte-Carlo (random) trial run shall then be made with the ramp initiated at the time of the chosen geometry (defined as t=0).

For Set 1, the run is to be continued until one of the following three events occur (1-3):

1) **Correct Exclusion:** The right satellite is excluded before the position error exceeds the HAL (HPL_{FD} in this test) for longer than the time to alert;

2) **Failed Exclusion:** A navigation alert is output due to detected positioning failure; or

3) **Missed Alert:** The position error exceeds the HAL (HPL_{FD} in this test) for longer than the time-to-alert without a navigation alert (this could

be due to missed detection or wrong exclusion).

For **Set 2**, the run is to be continued until one of the following three events occur (4-6):

4) **Correct Exclusion**: The right satellite is excluded before the position error exceeds the HAL (HEL_{FD} in this test) for longer than the time to alert;

5) **Failed Exclusion**: A navigation alert is output when the position error exceeds the HEL_{FD} for longer than the time to alert; or

6) **Missed Alert**: The position error exceeds the HAL (HEL_{FD} in this test) for longer than the time-to-alert without a navigation alert (this could be due to missed detection or wrong exclusion).

Since the receiver equipment may not be aware of the HAL, it is acceptable for a navigation alert to be output prior to exclusion. The run should be continued until the occurrence of one of the three outcomes listed above (4-6).

A total of 1650 trials shall be run for each of the 20 geometries in Set 1 and the 20 geometries in Set 2. The number of occurrences of each outcome shall be recorded for each geometry set defined in Section 2.4.2.7.3.2.

2.4.2.7.3.4 Pass/Fail Criteria

For the equipment to pass, the total number of events for each satellite set shall be less than or equal to the numbers shown in Table Appendix 1-

8.

Table Appendix 1-8 MAXIMUM NUMBER OF OUTCOMES TO OFF-LINE FDE TEST

Outcome	SET 1	SET 2
a. Failed Exclusion (true alert)	N/A	47
b. Missed Alert (Missed Detection or Wrong Exclusion)	47	47

Note: The number of test runs is designed to ensure a high probability of passing the test properly, and a low probability of falsely passing the test. The probability that properly designed equipment passes the missed alert and failed exclusion tests is 99%, while the probability that equipment with a missed alert or wrong exclusion probability of 0.002 is only 1% likely to pass the test.

2.4.2.7.4 False Alert Rate Test

The false alert rate is the rate with which the equipment flags the outside world that its position is outside the HPL, with the actual position still being inside the HPL (no positioning failure occurred). The false alert rate does not depend on the geometry of the visible satellites, false alerts will be driven either by ionospheric error or receiver noise. These tests use the same 40 geometries that are used in Section 2.4.2.7.3.

The tests are classified in two categories, depending upon the algorithm implementation. The test for snapshot algorithms takes advantage of the fact that single samples of ionospheric error, or receiver noise can be modeled as a simple Gaussian distribution. The test for non-snapshot algorithms must model the correlated effect of the error source over the correlation time.

2.4.2.7.4.1 False Alert Rate Simulations for Snapshot Algorithms

For each of the geometries defined in Section 2.4.2.7.3, a total of N=2,475,000 independent samples are simulated. The number N is determined by dividing the required total number of samples (99,000,000) by 40 geometries, yielding 2,475,000 sample points per geometry. For each sample, the satellites used for positioning are selected, the pseudoranges to the selected satellites are calculated, the FDE algorithm is executed and the result is logged. The number of geometries must be higher if the alert threshold is not set based upon the geometry. In this case, the number of geometries should be selected such that an algorithm with a true false alert rate of or equal to 6.66 $x10^{-7}$ per sample has a 0.01 chance of passing.

For each geometry, the number of false alerts is counted. To pass the false alert test, the following criteria shall be met:

(1) The total number of alerts over all admissible geometries shall be equal to or less than 47.

(2) For each geometry, there shall be no more than 3 alerts.

The first criterion ensures compliance with the overall false alert rate requirement. The second criterion ensures that there will be no unusual bunching of alerts at any position.

Note: To test the false alert probability with statistical confidence, a total number of 99,000,000 statistically independent samples have to be *taken. Of these, a maximum of 47 samples may be allowed to have a false alert.*

2.4.2.7.4.2 False Alert Rate Simulations for Non-Snapshot Algorithms

For each of the geometries defined in Section 2.4.2.7.3, a total of N=82,500 hours of operation is to be simulated. The number N is determined by dividing the required total number of simulation hours (3,300,000) by 40 geometries, yielding 82,500 hours per geometry. During each simulation run of 82,500 hours, the satellite velocities are to be set to zero, and the satellite positions are to be frozen at the values for the selected marginal geometry. This ensures that the HAL/HPL will not change during the run.

For the purpose of this test, a false alert is defined as the occurrence of an alert indication in the absence of a real positioning failure, regardless of how long the alert indication is provided. The total number of alerts shall be counted. Only the number of indication occurrences will be counted, not the duration of the indication. To pass the false alert test, the following criteria shall be met:

1) The total number of alerts over all admissible geometries shall be less than or equal to 47.

2) There shall be no more than 3 alerts for each admissible geometry.

The first criterion ensures compliance with the overall false alert rate requirement. The second criterion ensures that there will be no unusual clustering of alerts at any one position.

Note: The false alert rate for non-snapshot algorithms cannot be easily converted into a false alert probability. For these algorithms, a total number of 3,300,000 hours of operation has to be simulated to gain statistical confidence. During this simulation, no more than 47 false alerts can be allowed for the equipment to pass the test.

2.4.2.7.5 On-Line Verification Test

The purpose of the on-line verification tests is to ensure that the off-line algorithms and the on-line implemented algorithms are identical in function, performance, and computational (logical and arithmetic) results. This requirement is derived from the fact that all statistical performance results are determined by the off-lines tests.

Because the off-line and on-line tests use fundamentally different data generators, it is not possible to ensure that any off-line and on-line tests, under identical scenarios, will produce identical results. Therefore, there shall be two separate tests: an on-target computational test; and, an on-line behavioral test.

2.4.2.7.5.1 On-Target Computational Test

The purpose of the on-target test is to ensure that software on the target processor (in the BDS equipment) produces equivalent output data as the off-line algorithm, for identical input data. This test does not have to be conducted if the off-line tests described in Sections 2.4.2.7.3 and 2.4.2.7.4

are performed on the target processor using the same FDE software and parameter values used in the BDS equipment.

For the purpose of this test, equivalent means that arithmetic variables are within 0.1 meter of the off-line values and all logical variables are strictly identical (including logical counters, etc.).

The on-target test requires that the target software be exercised by forty satellite scenarios; one from each constellation in Set 1 and Set 2 as defined in Section 2.4.2.7.3.2. A ramp failure shall be generated as defined in Section 2.4.2.7.3.2 in each case.

1) For each satellite static scenario, the input data to the off-line navigation/FDE algorithm shall be recorded with its computational results. At a minimum, the computational results shall include the HPL_{FD}, horizontal radial position error, alert flag, and loss of integrity flag. Any additional variables internal to the navigation/FDE algorithm may also be recorded.

2) This input data will be duplicated in the on-target software and the input data will exercise the on-target navigation/FDE software. The computational results of the on-target software will be recorded and compared to the off-line results. The strict meaning of equivalent is defined above. The computational results for the on-line and on-target implementations are required to be equivalent.

2.4.2.7.5.2 On-Line Behavioral Test

The test shall be run using five constellations selected from the forty used under Section 2.4.2.7.5.1 that have a relatively constant HPL_{FD} and HEL_{FD} for the duration of the test. A ramp failure shall be generated as defined in Section 2.4.2.7.3.3 in each case. All test scenarios will be conducted with the equipment stationary (non-dynamic).

To pass the behavioral test:

1) The equipment position fixing difference shall only exceed 5 meters for periods of 2 seconds or less.

2) The equipment HPL_{FD} difference shall only exceed 50 meters for periods of 10 seconds or less.

If these thresholds are exceeded, the cause of the difference shall be identified and that cause must be within the expected characteristics of the algorithm.

2.4.2.8 Dynamic Tracking

Set up the equipment as indicated in Figure Appendix 1-1. The BDS Signal Generator shall be capable of simulating orbital parameters as defined in Appendix 7.

The capabilities identified in paragraph 2.2.3.5 shall be demonstrated by subjecting the equipment to the following tests.

a. Normal Maneuvers

(1) Allow the equipment under test to acquire the simulated satellite signals, and verify that the 2D accuracy requirements of section 2.2.2 are

met. Within the specified ground speeds shown below, simulate a 0.58g along-track acceleration. Reduce the acceleration to zero (unaccelerated flight), and observe that the 2D accuracy requirements of section 2.2.2 are met within 10 seconds.

(2) Allow the equipment under test to acquire the simulated satellite signals, and verify that the 2D accuracy requirements of section 2.2.2 are met. Within the specified ground speeds shown below, simulate a 180-degree turn, up to and including 1.3 times standard rate (along-track acceleration not to exceed 0.58 g). Return to level, unaccelerated flight and observe that the 2D accuracy requirements of section 2.2.2 are met within 10 seconds.

(3) Allow the equipment under test to acquire the simulated satellite signals, and verify that the horizontal of section 2.2.2 are met. Within the specified ground speeds shown below, simulate a 0.5 g vertical acceleration. Reduce the acceleration to zero, and observe that the horizontal of section 2.2.2 are met within 10 seconds. Repeat the test using a -0.5 g vertical acceleration.

Flight Phase	Maximum Ground Speed
En Route	800 knots

b. Abnormal Maneuvers

Allow the equipment under test to acquire the simulated satellite signals and verify that the 2D accuracy requirements of section 2.2.2 are met. Within the specified ground speeds shown below, simulate a 2g acceleration. Reduce the acceleration to zero (unaccelerated flight), and observe that the 2D accuracy requirements of section 2.2.2 are met within 60 seconds.

Flight Phase	Maximum
En Route	800 knots

Appendix 2 Minimum Performance Standards for Class Gamma Equipment

1.0 Purpose and Scope

1.1 Introduction

This appendix contains the minimum performance standards for Class Gamma airborne equipment in the independent BDS airborne navigation equipment. Class Gamma equipment integrates BDS sensors with display controller ,provides longitude and latitude information, and includes waypoint navigation calculations to provide navigation function. The combined accuracy and integrity of the BDS sensors shall comply with the provisions in Appendix 1 and Appendix 2. Since Class Gamma equipment is composed of BDS sensors and navigation capabilities, the MPS for Class Gamma equipment is based on meeting the MPS for Class Beta equipment in Appendix 1, with the addition of relevant functions and test procedures for navigation capabilities.

1.2 System Characteristics

Based on Appendix 1, the following features are added:

1.2.1 Waypoint Definition

A waypoint may be identified in several ways, i.e., by name, number or location. Waypoint location is necessary in the computation of navigation information and to minimize pilot workload during time-critical phases of flight. At a minimum, enough waypoints should be provided to define the current and next two legs in the en route phase of flight and to define an approach and missed approach. If the equipment is designed for long-range en route navigation only, waypoint definitions for approach and missed approach can be omitted.

In some mechanizations, waypoints are entered into the equipment in terms of their latitude and longitude. In other equipment, a waypoint's location may be specified in terms of a bearing and distance from any place whose position is itself known to the RNAV equipment.

Fundamentally, RNAV equipment performing lateral navigation requires only one or, at the most, two waypoints at a time to provide navigation information. The number of waypoints that must be stored will be a function of the equipment mechanization (TO-FROM or TO-TO) and the flight phase (en route).

1.2.2 Course Selection

To perform one of the most fundamental functions expected of RNAV equipment, that of providing guidance information relative to a course TO or FROM the active waypoint, it is necessary to define the bearing of that course.

1.2.2.1 TO-FROM Equipment

In some equipment, it is necessary for the pilot to enter the desired course using a course selector or keyboard. Once entered, the course is applicable to the currently active waypoint, and the equipment must indicate whether, given the existing geometry, this course is TO or FROM that waypoint. TO-FROM equipment that is capable of storing more than one waypoint is often able to store inbound and outbound courses from these stored waypoints as well.

1.2.2.2 TO-TO Equipment

In another mechanization, the pilot is not normally required to enter a desired course. The course is defined by the great circle between successive waypoints stored in the flight plan. Equipment mechanized in this way normally always flies TO the active waypoint on the computed course. Upon reaching the waypoint, instead of flying FROM it, the equipment would be sequenced to the next succeeding waypoint, which would then become the active waypoint. The flight would then proceed TO that waypoint along this newly computed track.

1.2.3 Path Computation

The equipment should compute a desired path either on the basis of a selected course to a waypoint or by a direct path (great circle) between two waypoints. Computation methods are described in Appendix 3.

1.2.4 Coordinate Systems

RNAV equipment fall into two general categories depending on their frame of reference. The simplest case is that of the VOR/DME or "station-referenced" equipment, where the coordinate system is polar and centered on the currently tuned VOR/DME. Position in such equipment is known only in relation to that station but is usually expressed in terms of bearing and distance from a waypoint whose location is specified with respect to the reference VOR/DME. The other is the BDS Coordinate System (BDCS) provided by the BDS system or WGS-84 coordinate system, and either coordinate system can be used to output relevant information. To determine bearing and distance to any waypoint, the current position and the waypoint must be in a common reference system.

1.2.5 Lateral Steering Outputs

The basic requirements for RNAV guidance are normally provided by displays of cross-track deviation, waypoint distance and desired track.

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

On the basis of Appendix 1, the following requirements are added.

2.1.1 Operation of Controls

Controls intended for use during flight shall be designed to minimize errors and, when operated in all possible combinations and sequences, shall result in a condition whose presence or continuation would not be detrimental to the continued performance of the equipment.

Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

2.1.2 Accessibility of Controls

Controls that are not normally adjusted in flight shall not be readily accessible to the operator.

Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their function.

2.1.3 Control/Display Capability

A suitable interface shall be provided to allow data input, data output and control of equipment operation. It shall be possible for the operator to manually select waypoint(s). The control/display shall be operable with the use of only one hand.

2.1.4 Control/Display Readability

The equipment shall be designed so that all displays and controls shall be readable under all normal cockpit conditions and expected ambient light conditions (total darkness to bright reflected sunlight). All displays and controls shall be arranged to facilitate equipment usage.

Note: Limitations on equipment installations to ensure display readability should be included in the installation instructions.

2.1.5 Maneuver Anticipation

Maneuvers such as tums to intercept a new course; transitions to an established direct-to leg; changes in climb, descent, level-off or change of ascent/descent angle must be anticipated when operating in the airspace. This anticipation may be accomplished through computational techniques within the equipment, operational procedures or a combination of both.

Regardless of the method chosen to implement maneuver anticipation, aircraft performance envelopes directly influence the effectiveness of this requirement.

2.1.6 Update Rate

Navigation information used for display shall be updated at an interval of 1.0 second or less.

2.2 2D RNAV Functional and Accuracy Requirements-Standard Conditions

2.2.1 Equipment Functional Requirements

On the basis of Appendix 1, the following functional requirements are added.

2.2.1.1 Cross-Track Deviation

2.2.1.1.1 Numeric Display Information

Provide either a display or electrical signal output with the following requirements:

a. The display accuracy should be consistent with the resolution required for the current full-scale display range, see the central CDI display (see the table in paragraph "2.2.1.1.2 Non-Numeric Display Information" (1))

b. The equipment shall provide a numeric display or electrical signal output of cross-track deviation to at least ±20 NM (left and right). A minimum resolution of 0.1 NM within 0.1 NM~9.9 NM and 1.0 NM beyond shall be provided. The display may be pilot selectable.

Note 1: The numeric display need not be located with the cross-track display (subparagraph 2.2.1.1.2) or in the pilot's primary field of view. However, numeric displays integrated with non-numeric displays or within the pilot's primary field of view can reduce flight technical error (FTE). Both digital cross-track deviation and track angle error have been shown to reduce FTE.

Note 2: The integration of non-numeric track angle error data and non-numeric cross-track data into one display provides the optimum of situation and control information for the best overall tracking performance.

2.2.1.1.2 Non-Numeric Display Information

(1) The equipment shall continuously provide either a display or electrical output with the following requirements:

	En Route
Full-Scale Deflection（±NM）	5.0
Readability（Display Only，NM）	≤1.0
Minimum Discernible（Display Only，NM）	≤0.1
Resolution of Electrical Output Percentage of Full Scale（±）	1%
Accuracy of Centered Display（±NM）	0.2
Linearity of Display or Electrical Output Percentage of Full Scale（±）	20%

(2) A means shall be provided for manual selection of the applicable display sensitivities in (1). Additionally, the equipment shall display the

non-numeric scale sensitivity, or provide an electrical output to display this information on an external display.

2.2.1.2 Waypoint Distance Display

Distance to the waypoint shall be displayed on demand with a resolution of 0.1 NM or better up to a range of 99.9 NM from the waypoint, and it shall be 1.0 NM or better at greater ranges. The equipment shall have the capability to display values of distance to waypoints of at least 150 NM for TO-FROM equipment and at least 260 NM for TO-TO equipment.

Note: For en route operation with random route clearance, a much greater distance between waypoints may be desirable.

2.2.1.3 TO-FROM Indication

For TO-FROM equipment, a continuous display or electrical output shall be provided to show whether the aircraft is behind or ahead of the active waypoint relative to an imaginary line perpendicular to the desired path and passing through the active waypoint.

For TO-TO equipment, which allows overflying of the active waypoint, a continuous display or electrical output shall be provided to show when the aircraft has passed an imaginary line perpendicular to the desired path and is passing through the active TO waypoint.

2.2.1.4 Flight Path Selection

The equipment shall provide a means of selecting and displaying a flight path defined by two waypoints. Additionally, if a TO-FROM mode is provided, the equipment shall provide a means of selecting and displaying an active waypoint and a desired course through that waypoint. The entry and display resolution of such a selected course shall be one degree or finer.

Note: It is assumed herein that the selected course is entered digitally. If analog techniques are used, it shall be demonstrated that the error in selecting the course does not exceed 0.5 degree.

2.2.1.5 Waypoint Entry

Equipment shall at least provide the capability to manually enter and display (prior to its utilization in the flight plan) the coordinates of a waypoint in terms of latitude and longitude with a resolution of 0.1 minute or better. If the equipment provides the ability to enter a waypoint as a range and bearing from another waypoint, the waypoint input resolution shall be 0.1 NM and 0.1 degree or better.

2.2.1.6 Waypoint Storage

(1) The equipment shall provide an appropriately updatable navigation data base containing at least the following location information in terms of latitude and longitude with a resolution of 0.01 minute or better for the area(s) in which IFR operations are to be approved: VORs (and VORTACs), DMEs, NDBs, and all named waypoints and intersections shown on en route charts.

Note: Manual entry/update of navigation data base data shall not be *possible. (This requirement does not preclude the storage of "user defined data" within the equipment.)*

(2) The equipment shall provide the capability for entering, storing, and designating as part of the active flight plan a minimum of 9 discrete waypoints (including the active waypoint).

(3) Navigation data bases shall meet the standards specified in sections 3, 4, and 5 of RTCA/DO-200B,"Preparation, Verification and Distribution of User Selectable Navigation Data Bases" and sections 2 through 7 of RTCA/DO-201A, "User Recommendations for Aeronautical Information Services."

2.2.1.7 Waypoint or Leg Sequencing

Means shall be provided, either manually or automatically, to utilize a series of stored waypoints in any selected order. Provisions shall be made to display the identification of the active waypoint and to preview the next waypoint or leg available for activation. The active and stored waypoints need not be displayed simultaneously. Means shall be provided to indicate whether or not the displayed waypoint is the active waypoint.

(1) The equipment shall provide the capability to fly from the present position direct to any designated waypoint. Access to this feature shall be by means of a single action by the pilot. Selection of the desired "TO" waypoint may require additional actions.

(2) The equipment shall provide the capability for accomplishment of

holding patterns and procedure turns. Activation of this function shall at least:

a. Change automatic waypoint sequencing to manual.

b. Permit the pilot to readily designate a waypoint and select a desired course (by means of a numerical keypad entry, HSI course pointer, CDI omni-bearing selector, etc.) to or from the designated waypoint (TO/FROM mode operation is acceptable).

c. Retain all subsequent waypoints in the active flight plan in the same sequence.

d. Permit the pilot to readily return to automatic waypoint sequencing at any time prior to the designated fix ("TO" waypoint) and continue with the existing flight plan.

2.2.1.8 Position Display

The computed aircraft position shall be available for display in terms of range and bearing to or from the active or parent waypoint. Resolution of range and bearing shall be at least 0.1 NM and 1.0 degree up to 99.9 NM, then at least 1.0 NM and 1.0 degree beyond. Some equipment may also display this information in latitude/longitude. If displayed, it shall have a resolution of at least 0.1 minute.

2.2.1.9 Input Data Observation

The equipment shall provide capability for observation and amendment of flight plan/navigation data to a resolution as specified in subparagraph 2.2.1.5 prior to its utilization. When data are recalled from storage for validation purposes, they shall also be retained in storage. In multiple waypoint equipment, data inspection or observation shall not interrupt or in any way affect the navigation guidance.

2.2.1.10 Failure/Status Indications

The equipment shall indicate, independent of any operator action, the following:

(1) By means of a navigation warming flag on the navigation display:

a. The absence of power required for the navigation function.

b. Any probable equipment malfunction or failure affecting the navigation function.

c. Loss of navigation function.

(2) The followings are notified by means of an appropriately located annunciator:

a. When RAIM is not available, inadequate navigation data due to poor space vehicle geometry such that the navigation error exceeds the requirements in Appendix 1 Table Appendix 1-1.

c. Loss of the RAIM function.

(3) Additional navigation data (such as distance to waypoint, time to waypoint, ground speed, etc.) shall be removed or flagged when the adequacy of navigation information upon which this data is based cannot be assured.

Note 1: Presentation of a failure/status annunciation does not require removal of navigation information from the navigation display. Consideration should be given to continued display of navigation information concurrent with the failure/status annunciation when conditions warrant.

2.2.1.11 Equipment Computational Response Time After Waypoint Entry

The time lag between time of waypoint data input and display of navigation guidance derived from the data shall not exceed five seconds.

Note: Equipment outputs may be filtered or "eased on'" consistent with desired aircraft dynamics and operating conditions.

2.2.1.12 Flight Plan Capacity

Add the following requirement: The equipment shall provide the capability to create, display, and edit a flight plan consisting of a minimum of 9 waypoints. A means shall be provided to readily display each waypoint, individually or together, of the active flight plan (in sequence) for review.

2.2.1.13 Integrity Requirements

Class Gamma equipment should meet the integrity requirements in paragraph 2.2.1.2 of Appendix 1, and should provide warnings consistent with the integrity requirements for the expected flight phase.

2.2.2 2D Accuracy Requirements (95% probability)

The total of error contributions of the airborne equipment shall not exceed either error value listed in this paragraph. The reference spheroid shall use latitude/longitude values corresponding to BDS coordinate system ellipsoid. Since FTE factors are beyond the control of equipment manufacturer or installer, these error sources are not included in Table Appendix 2-1. When properly installed on the aircraft, equipment that meets the display characteristics requirements contained in this CTSO will provide acceptable FTE values.

Table Appendix 2-1 BDS RNAV 2D ACCURACY REQUIREMENTS

（95% Confidence）

Error Type	Oceanic（NM）	Routes（NM）
Position Fixing Error*	0.017	0.017
CDI Centering**	0.2	0.2

* Equipment error assumes an average HDOP of 1.5. BDS equipment waypoint input and output shall provide a resolution of 0.1 minute or better. Position fixing errors are static values.

** The maximum difference between the displayed cross-track deviation and the computed cross-track deviation.

2.3 Equipment Performance- Environmental Conditions

The environmental test and performance requirements of this equipment are performed in accordance with Appendix 3.

2.4 Equipment Test Procedures

Add the following content to Appendix 1.

2.4.1 Test Procedures

a. General

Add the following content to Appendix 1:

The equipment shall be tested in all modes of operation that allow different combinations of sensor inputs to show that it meets both the functional and accuracy criteria.

Two distinct types of bench testing should be performed. These are referred to as static and dynamic tests, respectively. Static tests use precise inputs to verify that input signal and data processing is accomplished in a manner such that outputs are within specified range, resolution and scale factor limits. Dynamic testing provides quantitative data regarding RNAV equipment performance using a simplified simulation of flight conditions. This testing, when properly performed and documented, will serve to minimize the flight test requirements.

It shall be the responsibility of the equipment manufacturer to determine that the "sensor" inputs, when presented to the RNAV equipment, will perform commensurate with the accuracy requirements of paragraph 2.2.2. Additional sensor inputs may be optionally provided to enhance RNAV capability and/or performance.

The equipment required to perform these tests shall be defined by the equipment manufacturer as a function of the specific sensor configuration of his equipment. The basic elements of test equipment necessary to perform the overall tests herein are shown on Figure Appendix 2-1. Since these tests may be accomplished more than one way, alternative test equipment setups may be used where an equivalent test function can be accomplished. Combinations of tests may be used wherever appropriate. System characteristics that cannot be evaluated by physical tests must be substantiated by analysis.

The test equipment signal sources shall provide the appropriate signal format to input the specific system under test without contributing to the error values being measured.

Tests need only be performed once unless otherwise indicated.

b. Cross-Reference

Table Appendix 2-2 indicates the correspondence between the requirements of Subsections 2.2 and 2.3 and the tests of this section. Add the following to Appendix 1:

Table Appendix 2-2 TEST LEVEL REFERENCE TABLE

Required Sections	**Subject**	**Test Paragraphs**
2.2.1.1	Cross-Track Deviation	2.4.1.7
2.2.1.2	Waypoint Distance Display	2.4.1.2
2.2.1.3	TO-FROM Indication	2.4.1.3
2.2.1.4	Flight Path Selection	2.4.1.7
2.2.1.5	Waypoint Entry	2.4.1.4
2.2.1.6	Waypoint Storage	2.4.1.4
2.2.1.7	Waypoint or Leg Sequencing	2.4.1.4
2.2.1.8	Position Display	2.4.1.7

Required Sections	Subject	Test Paragraphs
2.2.1.9	Input Data Observation	2.4.1.4
2.2.1.10	Failure/Status Indications	2.4.1.6
2.2.1.11	Equipment Computational Response Time	2.4.1.4

c. Test Setup

The basic elements of the test equipment necessary to perform these tests are contained in Figure Appendix 2-1

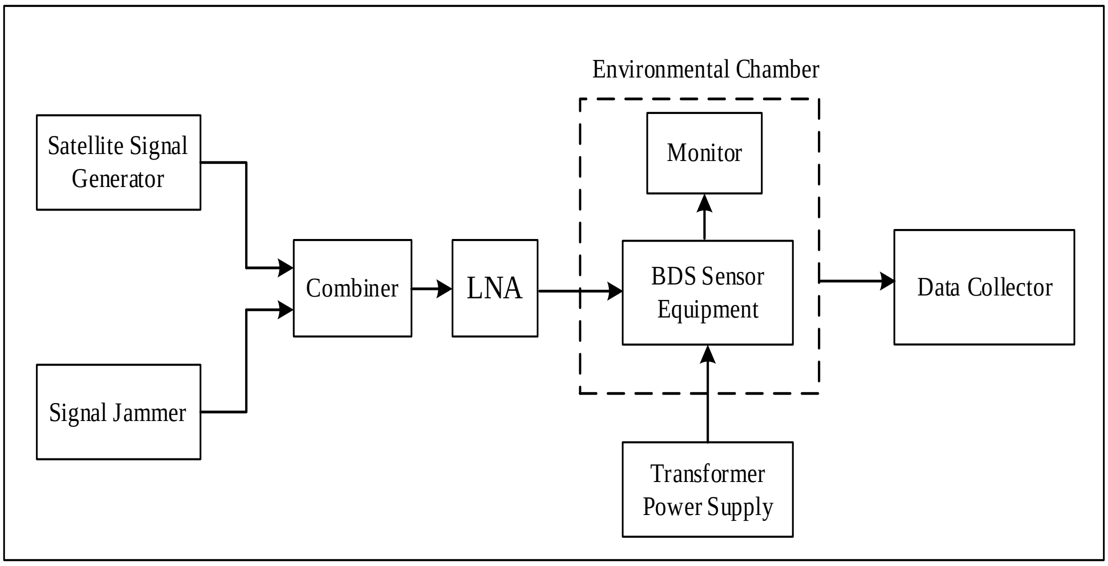

Figure Appendix 2-1 Reference Test Setup

2.4.1.1 2D Functional Performance

Each of the functional capabilities identified in subparagraphs 2.2.1.1 through 2.2.1.13 shall be demonstrated. These capabilities shall be evaluated either by inspection or in conjunction with the tests described in paragraph 2.4.1.

2.4.1.2 Waypoint Distance Display

Configure the equipment for static bench tests as defined in paragraph 2.4.1. Position the active waypoint 99.0 NM from the aircraft and verify the distance readout. Step the position in 0.1 NM increments from 99.0 to 99.3 NM and confirm the display resolution of 0.1 NM. Position the active waypoint at 140 NM for TO-FROM equipment (250 NM for TO-TO) and verify the distance readout. Step the position in 1 NM increments to 143 NM (253 NM for TO-TO) and confirm the display resolution to be at least 1 NM.

2.4.1.3 TO-FROM Indication

Set up the simulated aircraft location at Aircraft Location 1 of Figure Appendix 2-2. Enter the waypoints or waypoint and course to select Leg 1 for the route to be flown. Verify that a FROM indication is not given. Change the simulated aircraft location to Aircraft Location 3. Verify that either a FROM indication is given or that a warming of need for route update is given.

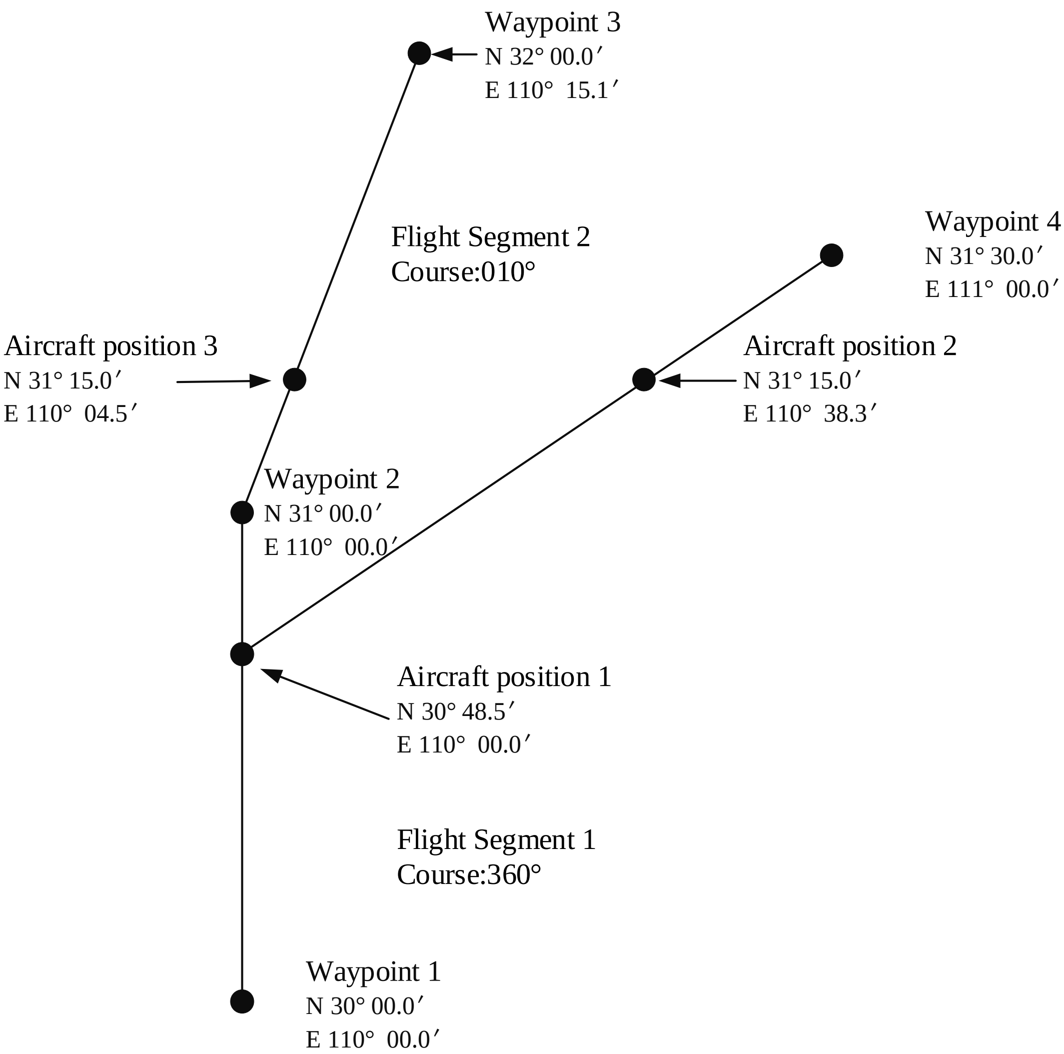

Figure Appendix 2-2 Waypoint or leg manipulation test

2.4.1.4 Waypoint Entry, Waypoint Storage, Waypoint or Leg Sequencing, Input Data Observation and Equipment Computational Response Time

Set up the simulated aircraft location at Aircraft Location 1 of Figure Appendix 2-2. Enter the waypoints or waypoint and course to describe Leg 1 and select Leg 1 for the route to be flown. Verify that guidance derived from flying this course is provided within five seconds. Verify that the system indicates the proper active waypoint(s). Enter the additional waypoint(s) to describe Leg 2. Verify that the system indicates that Leg 2 is not the active leg. Select Leg 2 as the active leg (enter course if a TO-FROM system) and verify that the system indicates the proper active waypoint(s). Recall and verify the coordinates of Waypoint 1. Amend Waypoint 1 to the coordinates of Waypoint 4. Verify that navigation guidance relative to Leg 2 is not affected.

Select a course direct to Waypoint 4. Change the aircraft location to Aircraft Location 2. Verify that an on-course indication is given.

2.4.1.5 BDS Device Integrity Alarm

The requirements and tests for barometric altitude assistance are optional to supplement Appendix 1.

2.4.1.6 2D Failure Indication

Connect the equipment as shown in Figure Appendix 2-1.

a. Remove the electrical power input to the equipment. There shall be a warning indication by the equipment.

b. The tests for the integrity of the navigation signals are specified in subparagraph 2.4.1.5.

2.4.1.7 2D Cross-Track Deviation Display

Connect the equipment as shown in Figure Appendix 2-1.

a. With equipment in the en route mode, adjust the BDS signal simulator to generate the indicated aircraft position on the BDS receiver. With the same BDS signal simulator conditions, establish each of the waypoint conditions of the tests in Table Appendix 2-3, and verify proper indication of the numeric and non-numeric cross-track indicators.

Table Appendix 2-3 CROSS-TRACK DEVIATION TEST

	Route：	Waypoint 1	Latitude：N 30 00.0'			
		Waypoint 2	Latitude：N 31 00.0'			
	Aft Position：		Latitude：N 31 30.0'		Longitude：E110 00.0'	
			Non-numeric Display		Numeric Display	
Test No.	Mode	Wpt 1&2 Longitude	Deviation	Tolerance	Deviation （NM）	Tolerance （NM）
1	En Route	E 110 07.0	>f.s.L	1/4 f.s.	6.0 L	0.3
2	En Route	E 110 05.8	f.s.L	1/4 f.s.	5.0 L	0.3
3	En Route	E 110.02.9	.5 f.s.L	.1 f.s.	2.5 L	0.3
4	En Route	E 110 00.0	Centered	.1 f.s.	0.0	0.3
5	En Route	E 109 57.1	.5 f.s.R	.1 f.s.	2.5R	0.3
6	En Route	E 109 54.2	f.s.R	1/4 f.s.	5.0 R	0.3
7	En Route	E 109 53.0	>f.s.R	1/4 f.s.	6.0 R	0.3
8	En Route	E 109 48.4	>f.s.R	1/4 f.s.	10.0 R	1.0
9	En Route	E 110 11.6	>f.s.L	1/4 f.s.	10.0 L	1.0
10	En Route	E 109 36.8	>f.s.R	1/4 f.s.	20.0 R	1.0
11	En Route	E 110 23.2	>f.s.L	1/4 f.s.	20.0 L	1.0

f.s. = Distance from center to full scale.

b. Re-establish the conditions of Test No.4. With the equipment in the en route mode, change the longitude of Waypoint 1 to E 109 59.8. Verify that all cross-track deviation displays/outputs show a discernible movement/change for test Cases 1 through 11.

Appendix 3 Equipment Performance - Environmental Conditions

The purpose of the environmental tests and performance requirements described in this appendix is to provide a test method for determining the overall performance characteristics of equipment under typical conditions that may be encountered in actual aviation operations. For all components in the stand-alone BDS airborne equipment, the environmental performance requirements specified in this appendix must be met.

Table Appendix 3-1 and Table Appendix 3-2 define the environmental test matrix for class Beta equipment and class Gamma equipment, respectively. For class Gamma equipment, additional tests in Table 3-2 should be carried out on the basis of completing the tests in Table 3-1. The shaded part in Table 3-1 and Table 3-2 is carried out when the equipment needs it. This table provides the paragraph numbers in RTCA/DO-160G describing each environmental test. These tests must be carried out in accordance with the test clauses specified in the table.

Some performance requirements in Appendix 1 and 2 do not require testing under all conditions covered by RTCA/DO-160G. If it can be shown that these specific performance parameters are not easily affected by environmental conditions based on calculation analysis, comparative analysis of similar designs, etc., and the performance levels specified in Appendix 1 and/or Appendix 2 will not be affected by exposure to such special environmental conditions. If a significant reduction occurs, such tests can be ignored.

Table Appendix 3-1 Class Beta Equipment environment test requirements

Class Beta Equipment	DO-160G requirements	Low Temperature Test Operating Test	Low Operating Temperature Test	High Short-Time Operating Temperature Test	High Operating Temperature Test	In-Flight Loss of Cooling Test	Altitude Test	Decompression test	Overpressure Test	Temperature Variation Test	Humidity test	Operational Shocks	Crash Safety Shocks	Vibration test	Explosion Proofness Test	Waterproofness Tests	Drip proof test	Spray Proof Test	Continuous Stream Proof Test	Spray Test	Immersion test	Sand and Dust Test	Fungus Resistance Test	Salt Spray Test	Magnetic effect test	AC Normal/abnormal operating conditions	DC Normal/abnormal operating conditions	Voltage Spike Conducted Test	Audio Frequency Conducted Susceptibility	Induced Signal Susceptibility Test	Radio Frequency Susceptibility Test	Emission of Radio Frequency Energy Test	Lightning induced transient sensitivity	Electrostatic discharge	Fire and Flammability Testing
Requirements	section	4.5.1	4.5.2	4.5.3	4.5.4	4.5.5	4.6.1	4.6.2	4.6.3	5	6	7.2	7.3	8	9	10.3.1	10.3.2	10.3.3	10.3.4	11.4.1	11.4.2	12	13	14	15	16.5.12	16.6.12	17	18	19	20	21	22	25	26
BDS UNHEALTHY Designation			×		×																														
Step detector			×		×																														
2D Accuracy Requirements（95% probability）			×	×	×	×	×	×	×	×	×	×		×		×	×	×	×	×	×	×	×	×		×	×	×	×	×	×		×	×	
BDS Acquisition Time																											×						×		

Class Beta Equipment	DO-160G requirements	Low Temperature Test Operating Test	Low Operating Temperature Test	High Short-Time Operating Temperature Test	High Operating Temperature Test	In-Flight Loss of Cooling Test	Altitude Test	Decompression test	Overpressure Test	Temperature Variation Test	Humidity test	Operational Shocks	Crash Safety Shocks	Vibration test	Explosion Proofness Test	Waterproofness Tests	Drip proof test	Spray Proof Test	Continuous Stream Proof Test	Spray Test	Immersion test	Sand and Dust Test	Fungus Resistance Test	Salt Spray Test	Magnetic effect test	AC Normal/abnormal operating conditions	DC Normal/abnormal operating conditions	Voltage Spike Conducted Test	Audio Frequency Conducted Susceptibility	Induced Signal Susceptibility Test	Radio Frequency Susceptibility Test	Emission of Radio Frequency Energy Test	Lightning induced transient sensitivity	Electrostatic discharge	Fire and Flammability Testing
Satellite Reacquisition Time																										×									
System operation																									×							×			

Note: In the table, one of the AC Normal/abnormal operating and DC Normal/abnormal operating is selected for testing according to the equipment situation.

Table Appendix 3-2 Class Gamma Equipment environment test requirements

Class Gamma Equipment	DO-160G requirements	Low Temperature Test Operating Test	Low Operating Temperature Test	High Short-Time Operating Temperature	High Operating Temperature Test	In-Flight Loss of Cooling Test	Altitude Test	Decompression test	Overpressure Test	Temperature Variation Test	Humidity test	Operational Shocks	Crash Safety Shocks	Vibration test	Explosion Proofness Test	Waterproofness Tests	Drip proof test	Spray Proof Test	Continuous Stream Proof Test	Spray Test	Immersion test	Sand and Dust Test	Fungus Resistance Test	Salt Spray Test	Magnetic effect test	AC Normal/abnormal operating	DC Normal/abnormal operating	Voltage Spike Conducted Test	Audio Frequency Conducted	Induced Signal Susceptibility Test	Radio Frequency Susceptibility Test	Emission of Radio Frequency Energy Test	Lightning induced transient sensitivity	Electrostatic discharge	Fire and Flammability Testing
Requirements	section	4.5.1	4.5.2	4.5.3	4.5.4	4.5.5	4.6.1	4.6.2	4.6.3	5	6	7.2	7.3	8	9	10.3.1	10.3.2	10.3.3	10.3.4	11.4.1	11.4.2	12	13	14	15	16.5.1	16.6.1	17	18	19	20	21	22	25	26
Cross-Track Deviation		×		×	×	×	×	×	×	×	×	×		×			×	×	×	×	×	×	×	×		×	×	×	×	×			×		×
Waypoint distance display		×		×	×	×	×	×	×	×	×	×		×			×	×	×	×	×	×	×	×		×	×	×	×	×			×		×
Device Calculation Response Time		×		×	×	×				×	×												×			×	×	×	×	×			×		×
2D Accuracy Requirements （95% probability）		×		×	×	×	×	×	×	×	×	×		×			×	×	×	×	×	×	×	×		×	×	×	×	×			×		×

Note: In the table, one of the AC Normal/abnormal operating and DC Normal/abnormal operating is selected for testing according to the equipment situation.

Appendix 4 Calculation of geodesics on the WGS-84 ellipsoid

1.0 General

ICAO recommends that WGS-84 should be the world standard for airborne navigation systems. However, without publishing AIP data compatible with WGS-84 coordinates, navigation accuracy will be limited. En route operations will not be limited by accuracy, but the accuracy of the approach will be severely limited. An internationally accepted common navigation reference system is required before the earth reference system is adopted for all air navigation categories.

Adopting WGS-84 as the world standard for air navigation systems, the airborne guidance system will face the task of calculating heading commands in real time. The heading command will guide the aircraft along the shortest distance on the WGS-84 ellipsoid, starting from the current aircraft position to the desired destination. This problem is more difficult than the corresponding problem on the surface of a sphere. Therefore, this article provides a discussion. This appendix describes the geometry of the WGS-84 ellipsoid, defining the geodetic latitude and longitude of a point on the ellipsoid. Then, an algorithm to solve the following problem is given, which is called the inversion of the geodetic survey.

Given the geodetic latitude and longitude of two points on the WGS-84 ellipsoid, find the distance and bearing of the shortest path between the two points. This path is called a geodesic.

The corresponding problem on the surface of a sphere has the following well-known basic algorithm. Suppose you are given a pair of distinct, diastereomeric points on the sphere. (Recall that if two points on the ellipsoid are symmetrical with respect to the center of the ellipsoid, they are called antipodal points.) Thus, these two points and the center of the sphere define a plane. The intersection of this plane and the sphere yields two arcs, which together form a circle called a great circle. The shortest arc is the shortest path connecting the two points on the sphere.

For two corresponding points on a sphere, there are infinitely many planes containing the two points, as well as the center of the sphere. All arcs resulting from the intersection of any one plane with the sphere will be a geodesic. Therefore, in this case, the problem has no unique solution.

On a non-spherical ellipsoid, the situation is very different. (It is therefore inappropriate to call geodesics on non-spherical ellipsoids "great circles"). Especially those geodesics that are flat curves, their location is only along the meridian or along the equator. Furthermore, geodesics can usually only be calculated to an arbitrary level of accuracy with the help of iteration. If the termination condition is that ε is 10^{-12}, then an accuracy of within 1 mm can be produced (Unless it is the two points of the mapping, or approximate mapping. In that case, the geodesics are respectively non-unique, or for the problem data are highly sensitive to small changes in This accuracy is usually obtained in no more than 6 iterations. Compared with the "closed-form" approximation algorithm, the algorithm proposed in this paper is easier to implement in software.

2.0 Definition of Terms

In this appendix, the term ellipsoid refers specifically to an ellipsoid of revolution obtained by rotation around its minor axis. The two points on the minor axis that intersect the surface of the ellipsoid are called the north and south poles. The plane passing through the center of the ellipsoid and orthogonal to the minor axis is called the equatorial plane. The intersection of the equatorial plane and the ellipsoid forms a circle called the equator.

The geodetic latitude of a point on the ellipsoid refers to the angle between the orthogonal vector outward from the point on the ellipsoid and the equatorial plane. This angle is considered positive in the northern hemisphere and negative in the southern hemisphere.

Any plane that is orthogonal to the equatorial plane and passes through the center of the ellipsoid, intersects the ellipsoid to form an ellipse, called a meridian. An arbitrary meridian is chosen as the datum, and it is called the Greenwich meridian. The longitude of a point on the ellipsoid is the angle between the plane containing the meridian passing through the point and the plane containing the Greenwich meridian. (The longitude of the poles is undefined). Longitude is customarily expressed in degrees, measured eastward from the Greenwich meridian.

A curve traversing in a specified direction is called a directional curve.

The azimuth of a directional smooth curve on the ellipsoid describes the direction of a vector tangent to the curve at a particular point on the curve. Azimuth is usually expressed in degrees and is measured clockwise from the North Pole. (The local northing (true north) of a point on the ellipsoid is the direction of the vector that is tangent to the meridian at that point. Note that local northing is undefined at the poles, so the description of azimuth does not apply there.)

3.0 Name

B1：Latitude of origin in degrees.

L1：Longitude of origin in degrees.

B2：Latitude of destination in degrees.

L2：Longitude of destination in degrees.

α_1：Location of departure in degrees

α_2： Location of destination in degrees

s： Distance from origin to destination in meters (geodetic length in radians)

4.0 WGS-84 Parameter

a=6378137m（WGS-84 Semimajor axis ）

b=6356752.3142m（WGS-84 Semiminor axis ）

e^2=6.69437991013*10^{-3}（WGS-84 The square of the first eccentricity）

$(e')^2$ =6.73949674227*10^{-3}（WGS-84 The square of the second eccentricity）

f=3.35281066474*10^{-3}（WGS-84 flattening）

5.0 Geodesics Equations

1. Convert the latitude from degrees to radians

$$\phi_1 = \pi B_1 / 180$$

$$\phi_2 = \pi B_2 / 180$$

2. Calculate longitude difference in radian

$$\Delta L = (\pi / 180)(L_2 = L_1)$$

3. Calculate the reduced latitude in radians

$$\beta_1 = \tan^{-1}\left[(1-f)\tan(\phi_1)\right]$$

$$\beta_2 = \tan^{-1}\left[(1-f)\tan(\phi_2)\right]$$

4. Primary iteration

$$\lambda_0 = \Delta_L$$

5. Perform the following iterations until

$$\left|\lambda_{k+1} - \lambda_k\right| < \varepsilon$$

Where ε is the termination condition：

$$\sin\sigma = \left[\left(\cos\beta_2 \sin\lambda_k\right)^2 + (\cos\beta_1 \sin\beta_2 - \sin\beta_1 \cos\beta_2 \cos\lambda_k)^2\right]^{1/2}$$

$$\cos\sigma = \sin\beta_1 \sin\beta_2 + \cos\beta_1 \cos\beta_2 \cos\lambda_k \text{ ,}$$

$$\sigma = \mathrm{a}\tan 2(\sin\sigma, \cos\sigma) \text{ ,}$$

$$\sin\alpha = \frac{\cos\beta_1 \cos\beta_2 \sin\lambda_k}{\sin\sigma} \text{ ,}$$

$$\cos^2\alpha = 1 - \sin^2\alpha \text{ ,}$$

$$\cos 2\sigma_m = \begin{cases} \cos\sigma - \frac{2\sin\beta_1 \sin\beta_2}{\cos^2\alpha} & \cos^2\alpha \neq 0 \\ 0, & \text{otherwise} \end{cases}$$

$$C = \frac{f}{16}\cos^2\alpha\left[4 + f(4 - 3\cos^2\alpha)\right],$$

$$\lambda_{k+1} = \Delta L - (1 - C) f \sin\alpha\left\{\sigma + C\sin\sigma\left[\cos 2\sigma_m + C\cos\sigma(-1 + 2\cos^2 2\sigma_m)\right]\right\},$$

Where the function atan2 is defined as follows, according to FORTRAN:

$$\text{atan2}(Y,X) = \begin{cases} \tan\text{-}1(Y/X) & X>0 \\ \tan\text{-}1(Y/X)+\pi & X<0 \\ \pi/2 & X=0 \text{ and } Y>0 \\ -\pi/2 & X=0 \text{ and } Y<0 \end{cases}$$

6.The distance s, the respective directions α_1 and α_2 of the origin and destination, can be calculated according to the following formula:

$$u^2 = (e^t)^2\cos^2\alpha,$$

$$A = 1 + \frac{u^2}{16384}\left\{4096 + u^2\left[-768 + u^2(320 - 175u^2)\right]\right\}$$

$$B = 1 + \frac{u^2}{1024}\left\{256 + u^2\left[-128 + u^2(74 - 47u^2)\right]\right\}$$

$$\Delta\sigma = B\sin\sigma\{\cos 2\sigma_m + \frac{1}{4}B[(-1 + 2\cos^2 2\sigma_m)\cos\sigma - \frac{1}{6}B(-3 + 4\sin^2\sigma)(-3 - 4\cos^2 2\sigma_m)\cos 2\sigma_m]\}$$

$$s = bA(\sigma - \Delta\sigma)$$

$$\alpha_1 = \frac{180}{\pi} a\tan 2(\cos\beta_2 \sin\lambda_{k+1}, \cos\beta_1\sin\beta_2 - \sin\beta_1\cos\beta_2\cos\lambda_{k+1})$$

$$\alpha_2 = \frac{180}{\pi} a\tan 2(\cos\beta_1 \sin\lambda_{k+1}, -\sin\beta_1\cos\beta_2 - \cos\beta_1\sin\beta_2\cos\lambda_{k+1})$$

Note that α_2 is the orientation of the geodesic line to the destination, and the starting point of the geodesic line is at the departure point. The so-called back azimuth or the starting azimuth of the geodesic line refers to the geodesic line that leaves the destination and returns to the starting point, $\alpha_2 = \pm 180$.

6.0 Verification

The above algorithm is verified by calculating the distances and bearings between all the distinct columns of position pairs given in Section 2.4.2.1 of Appendix 1. The termination condition ε used has a value of 10^{-12}. In all 552 cases, the maximum number of iterations was 8, the mean was 4.92, and the median was 5.

The geodetic curve on the ellipsoid can be obtained by solving the following system of nonlinear ordinary differential equations, where the unknowns are the geodetic latitude B, longitude L, and azimuth α of each point on the geodesic, where the independent variable t is the arc length along the geodesic and divide by α .

$$\frac{dB}{dt} = \frac{(1-e^2\sin^2 B)^{3/2}\cos\alpha}{1-e^2}$$

$$\frac{dL}{dt} = \frac{\sqrt{1-e^2\sin^2 B}\sin\alpha}{\cos B}$$

$$\frac{d\alpha}{dt} = \sqrt{1-e^2\sin^2 B}\sin\alpha\tan B$$

For each starting point, distance and azimuth (at the starting point), the actual end point of the corresponding geodetic curve can be determined by using the Runge-Kutta-Fehlberg algorithm of order (4, 5), and a local truncation error tolerance of 10^{-14}, these formulas are digitally integrated and calculated. Then, the distance between the actual destination point and the desired destination point is calculated. In each case, this distance is less than two tenths of a millimeter.

In order to realize the convenience of the above algorithm from software, seven test examples are provided. The following Table Appendix 4-1 lists the geodetic latitude of the departure point, and the geodetic latitude and longitude of the destination (departure points are all on the Greenwich meridian.)

Table Appendix 4-1 Test sample input

Example	**Latitude of departure**	**Latitude of destination**	**Longitude of destination**
1	37.331931575000	26.128566516667	41.4765298027778
2	35.269791283333	67.370771216667	137.791198430556
3	1.0	-0.9982863222222	179.296674991667
4	1.0	1.02885977777778	179.771622900000
5	41.696077777778	41.6961666666667	0.00015555555555
6	30.0	37.8923516222222	116.321302341667
7	37.0	28.2601931527778	-2.6276469944444

Table Appendix 4-2 gives the test results for each example. (termination condition ε is 10^{-12})

Table Appendix 4-2 Test sample output

Example	**Starting azimuth α_1**	**Arrival azimuth α_2**	**Distance s**
1	95.4669065012712	118.100037749533	4085797.71045745
2	15.7398635998781	144.927624307827	8084459.01281178
3	89.0255041313847	90.9762395789926	19959214.6261821
4	5.00474503898775	174.995222917504	19779362.8384626

5	52.6771685463032	52.6772720298999	16.2833273117916
6	45.0000844826718	129.136526168938	10.002067.6833720
7	-165.000275690672	-166.421458799296	999975.508415485

Tables Appendix 4-3 shows the number of iterations required, the error (distance between the desired destination and the actual destination point) for each test case.

Table Appendix 4-3 Number of iterations required for each test case

Example	**Iterations**	**Errors**	**significant decimal**		
			α1	**α2**	**s**
1	5	$1.38189930304136*10^{-5}$	10	10	5
2	4	$5.62351088062680*10^{-5}$	7	9	4
3	5	$1.42575492953545*10^{-4}$	6	5	4
4	18	$1.41770874909204*10^{-4}$	8	7	4
5	3	$6.87589522482552*10^{-8}$	7	6	7
6	4	$4.84762978049413*10^{-5}$	9	9	4
7	5	$7.19785012259682*10^{-6}$	9	9	5

Note that the data shown in Table Appendix 4-2 is the initial output obtained by running the algorithm on a particular platform, and not all numbers are valid. The last 3 columns in Table Appendix 4-3 give the number of digits to the right of the decimal point, which are considered valid for each data in Table Appendix 4-2. These data, in turn, can be obtained by rounding the departure azimuth, arrival azimuth, and distance to different levels of precision in each case, as well as calculating the actual end point of the corresponding geodesic. (For Arrival Azimuth, departure and destination are interchanged. Start Azimuth can be replaced by Arrival Azimuth minus 180 degrees). The number of significant decimals is determined by the minimum precision level. This accuracy causes the error between the actual end point and the desired target point to be within 50% of the values given in Table Appendix 4-3.

Appendix 5 Navigation System Error and Error Budget

1.0 Introduction

This appendix reviews error budget assumptions, provides example error budgets to estimate the RNAV system accuracy, defines error budget calculation methodology and provides statistical interpretation of error components. An error budget should:

a. Considering equipment manufacture and installation.

b. Allow users to determine whether the expected aircraft tracking performance is consistent with their operational requirements.

c. Assist in the design of airspace procedures.

Error budgets must be simple because the available data base usually does not substantiate more than elementary statistical procedures.

This same lack of a data base is the reason that the root-sum-square (RSS) calculation procedure is almost universally accepted throughout the navaid industry to estimate system performance.

The RNAV errors are usually defined in terms of the lateral cross-track and along-track errors for two-dimensional(2D) desired flight paths (see Figure Appendix 5-1). Three-dimensional (3D) desired flight paths include the vertical coordinate. The RNAV output position measurements, as well as the guidance inputs to the lateral and vertical channels of the aircraft flight control systems (AFCS), are specified as particular errors.

Errors are contributed by each of the following sources:

a. Navigation system error.

b. RNAV computation error.

c. Display system error.

d. Course selection error (CSE).

e. Flight technical error (FTE).

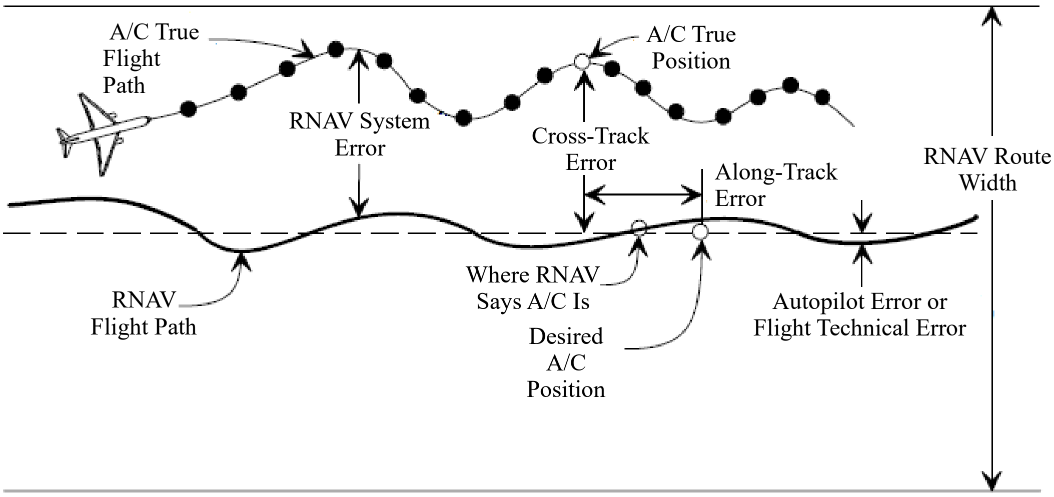

Figure Appendix 5-1 RNAV System Error

The combination of the navigation system errors and RNAV computation error is known as the system accuracy(error) or position fixing error. The combination of position fixing error with display error, CSE and FTE is known as system use accuracy.

2.0 Navigation Error Characteristics

2.1 Navigation System Error

Navigation system error is defined at the output of the NAV receiver and therefore it includes both the signal-in-space and airborne equipment error. The unique signal characteristics of a navigation system can have many error components including propagation error, errors in the transmitted signal arising from geographical siting, magnetic alignment of the ground station and receiver errors such as receiver noise. The distribution and rate change, as well as the magnitude of the errors, must be considered. Error distributions may contain both bias and random components. The bias component is generally easily compensated for when its characteristics are constant and known.

The distribution of the random or nonpredictable varying error component becomes the critical element to be considered in the design of navigation systems. The rate of change of the error within the distribution is also an important factor, especially when the system is used for approach and landing. Errors varying at a very high frequency can be readily integrated or filtered out in the aircraft equipment. Errors occurring at a slower rate can, however, be troublesome and result in disconcerting indications to the pilot. An example of one of these types of errors would be a "scalloped" VOR signal that causes the CDI to vary. If the pilot attempts to follow the CDI closely, the aircraft will start to "S-turn" frequently. The maneuvering will cause unnecessary pilot work load and degrade pilot confidence in the navigation system. This indication can be further aggravated if navigation systems exhibit different error characteristics during different phases of flight or when the aircraft is maneuvering.

In summary, the magnitude, nature and distribution of errors as a function of time, terrain, avionics, aircraft type, aircraft maneuvers and other factors must be considered. The evaluation of errors is a complex process, and the comparison of systems based on a single error number will be misleading.

2.2 RNAV Computation Error

Airborne equipment error components of navigation system error, in accordance with common practice, may include errors in the receiver outputs and errors contributed by the converter. In those cases in which an RNAV equipment accepts inputs directly from the NAV receiver, the error components normally included for the converter are not incurred; therefore, the appropriate value for airborne equipment error can be correspondingly reduced. The RNAV computation error can be estimated to be the output resolution of the RNAV equipment.

2.3 Display System Error

Display system error may include error components contributed by any input, output or signal conversion equipment used by the display as it presents either aircraft position or guidance commands (e.g., course deviation or command heading) and by any course definition entry devices employed. For systems in which charts are incorporated as integral parts of the display, the display system error necessarily includes charting errors to the extent that they actually result in errors in controlling the position of the aircraft relative to a desired path over the ground. To be consistent, in the case of symbolic displays not employing integral charts, any errors in waypoint definition directly attributable to errors in reference charts used in determining waypoint positions should be included as a component of this error. This type of error is virtually impossible to handle, and in general practice highly accurate published waypoint locations are used to the greatest extent possible in setting up such systems to avoid such errors (and to reduce workload).

2.4 Course Selection Error

Course selection error is the difference between the desired course setting and the course that is actually set.

2.5 Flight Technical Error

Flight Technical Error refers to the accuracy with which the aircraft is controlled as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include procedural blunders, which are gross errors in human judgement or inattentiveness that cause the pilot to stray significantly from the navigation flight plan.

It is difficult to completely characterize FTE. Equipment design and ambient environment variables affect FTE directly and measurably by affecting the processing of the basic display inputs. This includes determining the display scale factors and other display configuration variables which affect how guidance information is displayed. Compensating for aircraft control dynamics and air turbulence are examples of environmental variables which affect FTE. These factors must be taken into account in arriving at empirical values for FTE contribution to system use accuracy. Guidance signals can be coupled to the aircraft in one of three modes: Manual (Raw CDI deviations), flight director or autopilot.

Manual FTE—The FTE, which is associated with manual modes, will vary widely depending on such factors as wind conditions and the experience, workload, fatigue and motivation of the pilot. The currently used 95 percent probability manual FTEs for the various phases of flight Experience has shown, however, that FTE is related to navigation system and course sensitivity.

Table Appendix 5-1 gives the assumed FTE values in different flight phases to determine the RNAV system error budget.

Table Appendix 5-1 FTE assumption（95）

Flight Phase	**Manual (NM)**
Oceanic	2.0
En Route	1.0

2.6 RNAV Error Budgets

It is assumed in this appendix that the signals transmitted by the BDS system in its service area meet the requirements of the *Beidou navigation satellite system public service performance specification (version 3.0)* issued by the China Satellite Navigation System Administration Office.

The total positioning error of the BDS system should be equal to or less than the errors listed in Table Appendix 5-2a.

Note: Navigation accuracy is dependent on both HDOP and User Equivalent Range Error (UERE). UERE is comprised of URE, the space control segment or user range error, and UEE, the user equipment error. Variations of HDOP, URE and UEE will affect the overall accuracy of the system.

In order to formulate an overall positioning error budget, Table Appendix 5-2 b provides an example of composition error allocations for BDS position calculation. Composition errors are candidates for trade-offs, but trade-offs of position-fix errors must be within the limits of Tables Appendix 5-2 a and 5-2 b.

The RSS combination of position-fixing error with course selection error, display error and FTE is defined as the system use accuracy. While it is important that the total system use accuracy (including all error distributions) be consistent with that used by airspace planners in establishing protected airspace for instrument flight operations, it must be recognized that many of the factors affecting total system use error are beyond the control of the equipment manufacturer or installer. Error distribution from sources external to the airborne BDS receiving equipment are provided as examples based on the best data available at the time of publication and may change as technology improves.

Table Appendix 5-2a BDS Position Error Budget(1)

Error Source	**Error（Meters）**
Space	4.6**
Control	0*
User	
Ionospheric Delay Compensation	5.8***
Tropospheric Delay Compensation	0.25*
Receiver Noise and Resolution	5*
Multipath	0.45*
Other	0*
System UERE	9.0
Position Determination(2drms) (HDOP×σ×2) = (1.5×9.0×2)	27

*Refer to Section 2.1.2.1 of DO-316

** Refer to Beidou navigation satellite system public service performance specification (version 3.0)

*** Experience Reference Value

Table Appendix 5-2b BDS RNAV Error Budgets (2) (95%)

Error Source	**Error（NM）**
BDS Position Determination	0.015 (27m)
RNAV Computation	
Input Resolution (3)	0
Computation Output Resolution (4)	0
Position Fixing Error (5)	0.015

Notes：

(1) Calculate the BDS error budget using an HDOP of 1.5.

(2) Position fixing error is independent of operational use.

(3) RNAV calculation error (input / output resolution) is negligible. Table 2-3 of DO-283B gives the input / output resolution under RNAV,

which can be used for reference when necessary.

(4) It is applicable to allowable flight without considering dynamic error.

(5) The requirement for horizontal position point error is 27m.

When using manual flight, the system usage accuracy of BDS RNAV is a function of BDS position determination accuracy, course selection error related to waypoint entry resolution, course computation error dependent to RNAV equipment, display resolution and manual FTE. In different flight phases, after testing, the 2σ (95% probability) manual FTE is shown Table Appendix 5-1.

Table Appendix 5-2c lists the system accuracy requirements for the manual flight of BDS RNAV operated by TO-TO.

Table Appendix 5-2c System usage error during manual flight（95% Confidence）

Error Source	**Oceanic （NM）**	**Routes （NM）**
Position Fixing error	0.017	0.017
CDI Centering	0.2	0.2
flight technical error	2.0	1.0
System use accuracy	2.01	1.02

For equipment manufacturers and installers, the difficulty of providing FTE data without adequate statistics precludes FTE as a requirement for system licensing. Accordingly, system usage accuracy is not an established requirement, while system error or position determination accuracy is an established requirement. However, FTE values have been developed that can be used by system users and airspace planners.

Note: When specifying or describing system accuracy, it is complicated by the fact that some error components (eg, FTE) are linear (one-dimensional) while others provide 2- or 3-dimensional accuracy (eg, BDS position). When specifying linear accuracy, a 95% confidence level is usually used. When 2-dimensional accuracy is used, the drms uncertainty estimate is used, and 2drms, which is 2 times the horizontal radial error.

The definition of horizontal radial error refers to the root mean square value of the distance between the real position point and the position point in a set of observations. It defines a set of vertical coordinate axes in any direction for the first time, and the origin is at the real position point. frequently used. Then, the variances for each axis are summed and the square root is calculated. When the error is elliptically distributed, which often occurs in static, ground-based systems, these axes can be regarded as the major and minor axes of the error ellipse for simplicity. Thus, the confidence is related to the elongation of the error ellipse. When the error ellipse is flattened into a line, the confidence level of the 2drms measurement is close to 95%; when the error ellipse is rounded, the confidence level is close to 98%. All error budgets are conservative relative to the actual achievable accuracy due to the assumption of a 95% confidence level. This error budget can be used to reduce and equalize errors as long as the total error budget is not exceeded. The extent to which sensors or other components are used at this equilibrium for optimum *performance will be reflected in the installation instructions provided by the manufacturer. These directives are expected to include the basis to be formed for the restrictions on the use of equipment caused by equalization. FTE values above these must be compensated by corresponding reductions in other systematic errors. See the discussion of FTE in Section 2.5 of this appendix. FTE is not used in determining along-track accuracy.*

2.6.1 TO-FROM Course Computation Effects

In addition to the above-mentioned factors that affect the accuracy of calculating the location of BDS equipment, there are also computation errors related to the quality of the relationship between the position and the desired course when using an angular reference. Since the errors are relative to the angular input (1 degree), these errors are fairly small near the waypoint defined by the desired course, but increase as you move away from the waypoint. Due to the limited value of TO-FROM navigation using BDS as a sensor, and it is only expected to be used in short-distance vectoring, there will be no error in TO-FROM BDS RNAV navigation.

2.6.2 North reference effect

The BDS position determination accuracy is not dependent upon distance from the waypoint defining the route to be flown. However, when BDS is used on a route (TO-FROM operation) determined only by a radial (selected as 1.0 degree) to or from a waypoint, in the heading setting angle error, the overall system cross track accuracy is related to the BDS position determination accuracy and the distance to the waypoint. Any TO-FROM application should:

a. There are technical provisions to ensure proper north reference is used for course.

b. Be suitably restricted in range so that the resolution error remains within the error budget in the full heading of the published route.

Note: Relative to the VOR/DME defined waypoint heading navigation requirements, the greatest navigation errors are caused when those course are given in degrees from the VOR north. This "station north" may differ by more than 2 degrees from the current local magnetic north.

3.0 Statistical Significance of Test Bed Tests and Flight Verification Tests

Tracking error performance (see the Figure Appendix 5-1), or total system usage accuracy, is a combination of FTE and system position determination. The accuracy performance of the RNAV navigation system is specified with a 95% probability. This means that for a single trip along a defined flight path (eg, between two waypoints), 95% of all position measurements within the appropriate window must be within the specified cross-track error allowance. This means that 95 out of 100 flights must meet the specified cross-track error allowance. The measurement defines a confidence interval, the confidence limits of which is compared to an accuracy standard.. It is a confidence interval because the desired flight path is an unknown constant parameter that the navaid is estimating. The computed 95% confidence interval is a random variable covering an average of 95% of the expected path.

The error budget is defined as a 95% confidence limits rather than a 2σ limits because for Gaussian random processes, the two specifications are essentially the same. The probability that a given event will occur is an important quantity, not a 2σ value. The probability of exceeding a specified limits is only a meaningful measure used to determine air-lane route widths, decision windows, touchdown footprints and obstacle clearance surfaces.

While each error component can be given with a sample variance $S_N{}^2$, the calculation of the 95% confidence interval requires knowledge of the underlying probability distribution function that is often unknown. In practice, confidence intervals are estimated to avoid this lack of knowledge by using limits values of 2.5% and 97.5% determined from the measured data. Thus, the overall system error is determined by the RSS of 95% of the individual error component values. The confidence limits for the combined measured error samples are then compared to appropriate accuracy standards.

Based on the above definitions, it should be emphasized that the term "bias with 95% probability " means that 95% of the equipment bias measurements lie between the 2.5% and 97.5% limits of all navaids. The specified bias error values are the upper and lower percentile limits.

Combining error components on an RSS basis is used almost universally in the literature. The implicit assumptions are that the error components satisfy a linear model and that the errors are uncorrelated random variables with zero mean. The assumption of a linear model further implies that there is no coupling between the navigation system position determination error and the FTE.

The validity of the assumption of uncorrelated error components depends on several factors. Clearly, the error components are uncorrelated across all flight routes. For repeated flights on the same route, site-dependent errors may be correlated, while equipment bias errors are related to the nature of the drift mechanism. Bias errors are assumed to be fixed during a single flight mission.

Appendix 6 Standard Received Signal and Interference Conditions

1.0 Introduction

This appendix specifies the radio frequency interference environment of BDS receivers (navigation antennas) in and around the B1C band. It also describes the frequency selectivity of the smallest standard antenna. All signal levels in this appendix are specified in dBm measured at the antenna port. During the test, the interference signal shall be applied in accordance with the requirements of this appendix.

2.0 Operating Interference Environment

The interference levels specified in this appendix are defined at the antenna port and are independent of the antenna radiation pattern.

Figure Appendix 6-1 shows the operating interference environment. The figure shows that the areas with interference to bandwidths other than CW are considered to represent in-band and near-band interference, and the received power level is defined as a function of bandwidth in Figure Appendix 6-2. Figure Appendix 6-3 shows the frequency selectivity of minimum standard antenna to define the operating environment of equipment using such an antenna.

2.1 In-band and near-band interference

In-band and near-band interference environments are suitable for steady-state operation. After the steady-state navigation is established, when the interference power level of the antenna port is equal to the interference threshold specified in Table Appendix 6-1 and Figure Appendix 6-1, and the BDS B1C signal level at the antenna port is -133.5 dBm, the receiver should meet the performance goals. For the initial acquisition of the BDS B1C signal prior to steady-state navigation, the receiver should meet the performance goals when the in-band and adjacent-band interference levels are 6 dB below the limits for steady-state operation. The interference bandwidth is 3dB bandwidth.

Table Appendix 6-1 BDS B1C CW Interference Threshold for Steady State Navigation of Receiver

Interference Signal Frequency Range f_i	**Interference Level**
1315MHz < f_i ≤ 1525MHz	Linearly increased from -9 dBm to -1.5 dBm
1525MHz <f_i ≤ 1531MHz	Linearly decreased from -1.5 dBm to -4 dBm
1531MHz <f_i ≤ 1536MHz	Linearly decreased from -4 dBm to -35 dBm
1536MHz <f_i ≤ 1565.42MHz	Linearly decreased from -35 dBm to -120.5 dBm
1565.42MHz <f_i ≤ 1585.42MHz	-120.5 dBm
1585.42MHz <f_i ≤ 1610MHz	Linearly increased from -120.5 dBm to -30 dBm
1610MHz <f_i ≤ 1618MHz	Linearly increased from -30 dBm to -12 dBm*
1618MHz <f_i ≤ 2000MHz	Linearly increased from -12 dBm to 21.5 dBm*
1618MHz <f_i ≤ 1626.5MHz	Linearly increased from -30 dBm to 8 dBm**
1626.5MHz <f_i ≤ 2000MHz	Linearly increased from 8 dBm to 21.5 dBm**
f_i > 2000MHz	21.5 dBm

* Suitable for aircraft without onboard satellite communications

** Suitable for aircraft with airborne satellite communication

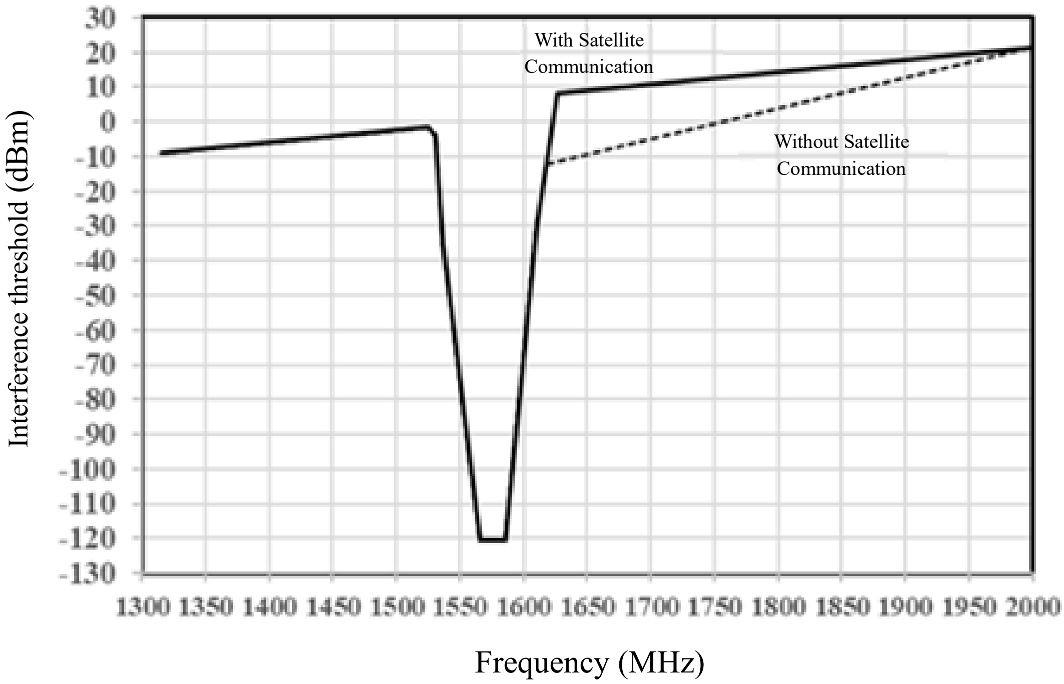

Figure Appendix 6-1 Interference power at the antenna port

After the steady state navigation is established, when there is a band-limited noise-like interference signal in the frequency range of 1575.42 $\pm BW_I/2$ MHz, and the power level of the interference signal at the antenna port is equal to Table Appendix 6-2 (power as a function of the interfering signal bandwidth BWI) and the interference threshold specified in Figure Appendix 6-2, and the receiver should meet the performance goal when the BDS B1C signal level at the antenna output is –133.5 dBm. During the initial acquisition of the BDS B1C signal before steady state navigation, the receiver should meet the performance goal when the interference threshold is 6 dB lower than that specified in Table Appendix 6-2.

Note: BW_I is the equivalent noise bandwidth of the interfering signal.

Table Appendix 6-2 BDS B1C receiver steady navigation band limit noise interference threshold

Bandwidth	Interference Level
0 ≤BW_I≤ 700 Hz	-120.5 dBm
700 Hz < BW_I ≤ 10 kHz	Linear increase from -120.5 dBm to -113.5 dBm
10 kHz < BW_I≤ 100 kHz	Linearly increased from -113.5 dBm to -110.5 dBm
100 kHz < BW_I ≤ 1 MHz	-110.5 dBm
1 MHz < BW_I ≤ 20 MHz	Linearly increased from -110.5 to -97.5 dBm*
20 MHz < BW_I ≤ 30 MHz	Linearly increased from -97.5 to -91.1 dBm*
30 MHz < BW_I ≤ 40 MHz	Linearly increased from -91.1 to -89.5dbm *
40 MHz < BW_I	-89.5 dBm*

* The interference level does not exceed -110.5 dBm/MHz in the frequency range of 1575.42 ± 10MHz.

The relationship between Fig. 6-1 and Fig. 6-2 is as follows: At 1575.42MHz ± 700/2 Hz, between the threshold in Fig. 6-1 (the threshold varies with the bandwidth) and the 0 to 700 Hz bandwidth in Fig. 6-2 the interference power level. For interference whose bandwidth exceeds this range, the threshold level (the level of mask) in Figure Appendix 6-1 is adjusted up or down according to the level in Figure Appendix 6-2. For example, for the upper curve in Figure Appendix 6-2, interference with a bandwidth of 10kHz lowers the threshold to the CW interference threshold at -113.5dBm, while interference with a bandwidth of 20MHz raises the threshold to 1575.42MHz, the level is -97.5dBm.

For the interference signal whose center frequency deviates from 1575.42MHz, the description of its interference threshold will be updated in subsequent editions of this specification.

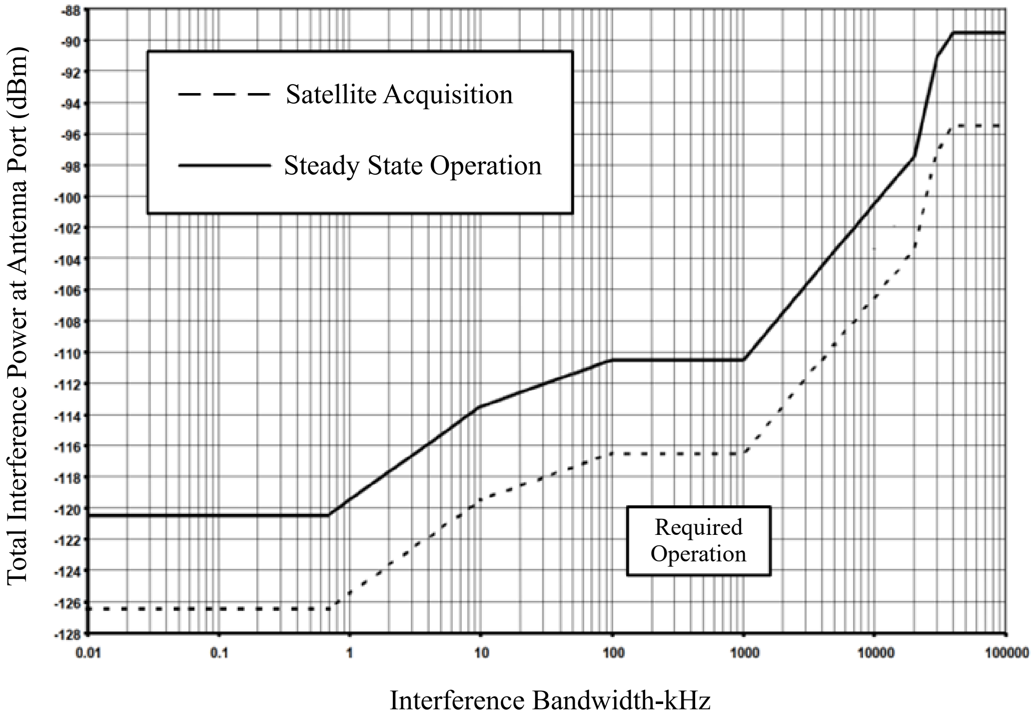

Figure Appendix 6-2 In-band and near-band interference environments

2.1.1 In-band and Near-band Interference Environments

After entering a stable navigation state, equipment operating during all phases of flight may receive out-of-band impulse interference within the in-band frequency range specified above with the characteristics described below:

Table Appendix 6-3 In-band and near band pulse interference

	BDS
Peak Power	+10 dBm
Pulse Width	≤ 125us
Pulse Duty Cycle	≤ 1%
Signal Bandwidth	≥ 1 MHz

2.1.2 GNSS Noise

GNSS noise is broadband noise whose spectral density affects the device as much as the total power from the expected future GNSS environment. Due to different signal coupling and operational requirements, values for different receiver functions are specified in Table Appendix 6-4.

Table Appendix 6-4 Effective noise density of all GNSS sources

Receiver function	Effective noise density (dBm/Hz)
Initial capture (BDS only)	-172.2
BDS trace and recapture	-171.9

2.2 Out of band Interference

Out-of-band continuous wave (CW) interference signals may be as high as the levels specified in Table Appendix 6-1 and Figure Appendix 6-1.

2.2.1 Out of band pulse Interference

After entering a stable navigation state, equipment operating during all phases of flight may experience out-of-band impulse interference within the above-specified out-of-band frequency range with the characteristics described below:

Table Appendix 6-5 out-of-band pulse interference

	BDS
Peak Power	+30 dBm
Pulse Width	≤125us
Pulse Duty Cycle	≤1%

3.0 Minimum Standard Antenna Frequency Selectivity

When received by a minimum standard antenna, the interfering signals are at least attenuated according to the frequency selectivity shown in Table Appendix 6-6 and Figure Appendix 6-3.

Table Appendix 6-6 Frequency Selection

Frequency (MHz)	Selectivity (dB)
1315 ≤ f < 1504.42	-50 dB
1504.42 ≤ f < 1554.42	Linearly increased from -50 dB to -5 dB
1554.42 ≤ f < 1558.42	Linearly increase from -5 dB
1558.42 ≤ f ≤ 1591.92	0 dB
1591.92 < f ≤ 1605.42	Linearly decreasing to -25.35 dB
1605.42 < f ≤ 1625.42	Linearly decreasing from -25.35 dB to -50 dB
1625.42 < f ≤ 2000	-50 dB

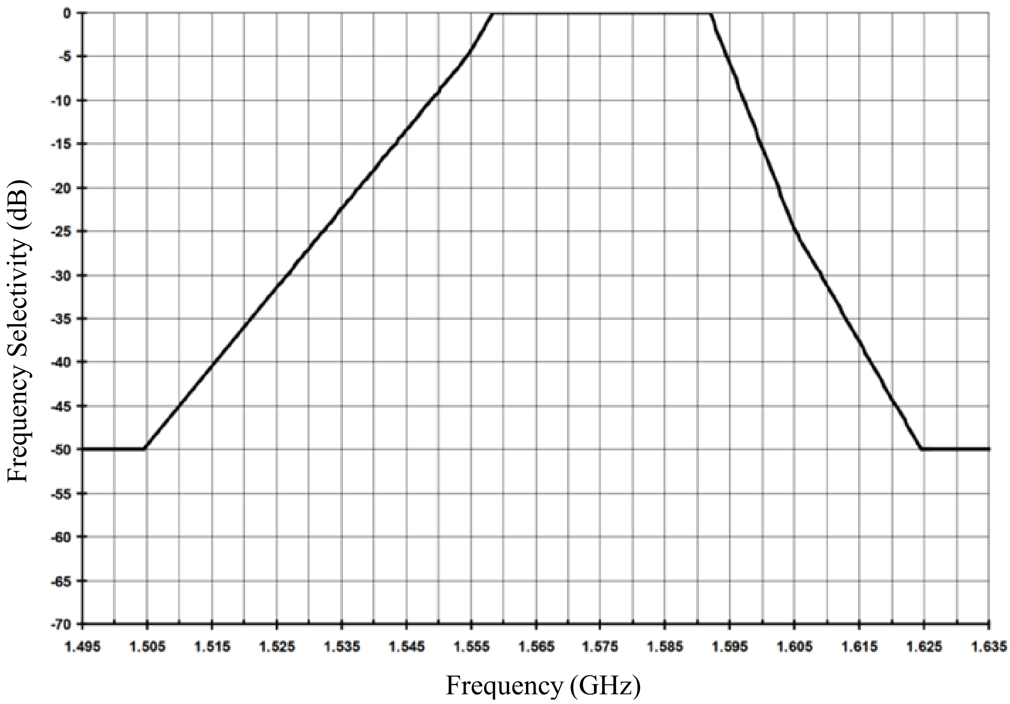

Figure Appendix 6-3 frequency selectivity

Appendix 7 Orbital Parameters

Optimal 27BDS space vehicle constellation ephemeris:

Date：2020.12.31 00:00:00

Data sources：http://www.csno-tarc.cn/system/almanac

Almanac reference time: Beidou 782 weeks, 345600 seconds

PRN	SVN	Eccentricity	Orbital Inclination (rad)	Rate of Right Ascen (r/s)	SQRT (m^1/2)	Right Ascen at Week (rad)	Argument of Perigee (rad)	Mean Anom (rad)	Af0 (s)	Af1 (s/s)
19	MEO-1	5.8755639475E-004	0.9651605758	-6.323477683E-009	5282.628511	5.8751097569E-001	-1.196060029	2.4481426819E+000	6.7326391E-004	1.365574E-011
20	MEO-2	5.3267576732E-004	0.9651569112	-6.405981120E-009	5282.627695	5.8813228285E-001	-0.523406886	2.5373690399E+000	-9.0964219E-004	1.031175E-012
21	MEO-3	4.3597316835E-004	0.9644380157	-6.420267429E-009	5282.628443	5.8990249565E-001	-0.800287154	4.8008198152E-001	-7.7364267E-004	-1.441957E-011
22	MEO-4	4.5954983216E-004	0.9644476388	-6.379194290E-009	5282.629004	5.8981621420E-001	0.221834956	2.3992907314E-001	-8.2987511E-004	-1.119104E-011
23	MEO-5	1.9643339329E-004	0.9508712821	-6.677063840E-009	5282.618404	2.6960637336E+000	-0.243972443	1.7622103419E+000	-8.8668242E-004	4.715339E-012
24	MEO-6	7.0187018719E-004	0.9508627782	-6.647062591E-009	5282.614874	2.6958827516E+000	0.384053888	2.7256341678E+000	-7.3509372E-004	-4.770406E-012
25	MEO-11	5.0044874661E-004	0.9520681466	-6.682421206E-009	5282.621058	2.6703494051E+000	0.332731900	1.9570175239E+000	-8.8036770E-004	-1.331645E-011
26	MEO-12	7.8595802188E-004	0.9521230777	-6.661348900E-009	5282.621683	2.6709102338E+000	0.294989487	-2.7263048206E+000	9.6114119E-004	1.416289E-011

PRN	SVN	Eccentricity	Orbital Inclination (rad)	Rate of Right Ascen (r/s)	SQRT (m^1/2)	Right Ascen at Week (rad)	Argument of Perigee (rad)	Mean Anom (rad)	Af0 (s)	Af1 (s/s)
27	MEO-7	4.8369425349E-004	0.9662552101	-7.237801483E-009	5282.621870	-1.4842799602E+000	0.816988194	-2.1923753642E+000	4.5826181E-004	6.393996E-012
28	MEO-8	2.7135224082E-004	0.9661514512	-7.202085710E-009	5282.616467	-1.4844415731E+000	-2.105974915	1.5191537035E+000	-1.2762553E-004	4.570566E-012
29	MEO-9	4.4684507884E-005	0.9651989409	-7.250302004E-009	5282.616772	-1.5226934811E+000	0.814345947	2.5246449691E+000	3.3193733E-004	5.197620E-012
30	MEO-10	4.0892674588E-004	0.9651394235	-7.279588938E-009	5282.617266	-1.5221507619E+000	-0.145686359	-1.9946909340E+000	4.2460812E-004	5.417000E-012
32	MEO-13	2.5471195113E-004	0.9638246581	-6.483841506E-009	5282.629107	5.8238996073E-001	-1.287952332	-2.1726881120E+000	-8.8142871E-004	-7.815970E-013
33	MEO-14	2.2743048612E-004	0.9638562074	-6.385265972E-009	5282.625898	5.8223721160E-001	0.044476313	-1.9302165779E+000	-8.9289119E-004	-1.651656E-011
34	MEO-15	4.4674077071E-004	0.9632590457	-7.383164681E-009	5282.622993	-1.5189910534E+000	0.123650617	8.5005845493E-001	-7.7428249E-004	8.604672E-012
35	MEO-16	6.4256507903E-004	0.9633293798	-7.289946512E-009	5282.618286	-1.5191263162E+000	-0.096660823	2.6630348908E+000	-4.8854923E-004	1.782041E-011
36	MEO-17	6.5148144495E-004	0.9522654123	-6.665991951E-009	5282.616556	2.6933814308E+000	-1.356669272	5.1809095730E-001	-7.8957213E-004	1.023359E-011
37	MEO-18	6.5263698343E-004	0.9522785245	-6.671706474E-009	5282.615540	2.6932193673E+000	-0.741249787	1.4856393782E+000	-8.6150330E-004	1.297628E-012
38	IGSO-1	1.7115174560E-003	0.9737755322	-2.243664886E-009	6493.043236	-6.4788742908E-001	-2.832535970	-7.5919540319E-001	1.2100161E-004	2.253308E-012
39	IGSO-2	1.6683918657E-003	0.9602768316	-2.016512567E-009	6493.159714	1.4064549171E+000	3.127404627	-2.5918085680E+000	2.6906607E-005	6.137312E-013
40	IGSO-3	1.9474010915E-003	1.0148284806	-1.414701785E-009	6493.401602	-2.6889769926E+000	-2.947002163	1.3089077415E+000	1.1631473E-004	3.544720E-012
41	MEO-19	1.2286180863E-003	0.9626940930	-6.447054260E-009	5282.624773	5.8656965812E-001	-1.772140033	-8.9711588478E-001	-9.3464867E-004	-5.598632E-011
42	MEO-20	1.0854690336E-003	0.9627320528	-6.441696894E-009	5282.630098	5.8710341256E-001	-1.419609052	3.1991468674E-001	-7.6889968E-004	-2.241939E-011

PRN	SVN	Eccentricity	Orbital Inclination (rad)	Rate of Right Ascen (r/s)	SQRT (m^1/2)	Right Ascen at Week (rad)	Argument of Perigee (rad)	Mean Anom (rad)	Af0 (s)	Af1 (s/s)
43	MEO-21	4.3196568731E-004	0.9602355334	-7.338877122E-009	5282.614906	-1.5175742494E+000	-0.018438167	2.3408523182E-001	-5.3019076E-004	-1.707789E-011
44	MEO-22	6.3246453647E-004	0.9606886035	-7.383164681E-009	5282.620522	-1.5176224540E+000	0.030127465	1.7448549548E+000	-3.8390513E-005	1.960032E-011
45	MEO-23	5.4635305423E-004	0.9561524808	-6.634919228E-009	5282.616070	2.6935093689E+000	-0.101332451	-1.5241274524E+000	3.2230466E-004	1.008881E-011
46	MEO-24	8.3854910918E-004	0.9561850424	-6.649562695E-009	5282.622826	2.6940254074E+000	-0.150690933	8.5037888958E-002	4.7460873E-004	-1.717914E-011

Appendix 8 ACRONYMS

Acronym	Meaning
AFCS	Automatic Flight Control System
BDCS	BeiDou Coordinate System
BDS	BeiDou Navigation Satellite System
BW	Bandwidth
CAAC	Civil Aviation Administration of China
CDI	Course Deviation Indicator
CDU	Control Display Unit
CSE	Course Select Error
CTSO	Chinese Technical Standard Order
CTSOA	Chinese Technical Standard Order Authorization
CW	Continuous Wave
CWI	Continuous Wave Interference
DIF	Data Integrity Flag
DME	Distance Measure Equipment
DOP	Dilution of Precision
drms	Distance Root Mean Square
ETA	Estimated Time of Arrival
FAF	Final Approach Fix
FD	Fault Detection
FDE	Fault Detection and Exclusion
FE	Fault Exclusion
FMS	Flight Management System
FTE	Flight Technical Error
GBAS	Ground-Based Augmentation System
GDOP	Geometric Dilution of Precision
GNSS	Global Navigation Satellite System
HAL	Horizontal Alert Limit
HDOP	Horizontal Dilution of precision
HEL	Horizontal Exclusion Level
HFOM	Horizontal Figure of Merit

HPL	Horizontal Protection Level
HS	Health Status
HUL	Horizontal Uncertainty Level
Hz	Hertz (cycles per second)
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IOD	Issue of Data
IODC	Issue of Data Clock
IODE	Issue of Data Ephemeris
I/S	Interference-to-Signal Ratio
LDA	Localizer Direction Apparatus
LNA	Low Noise Amplifier
LNAV	Lateral Navigation
LOC	Localizer
m	Meters
MAP	Missed Approach Point
MLS	Microwave Landing System
MOPS	Minimum Operational Performance Standards
MSL	Mean Sea Level
NAV	Navigation
NDB	Non-Directional Beacon
NIS	Number of Independent Samples
NM	Nautical Mile
NPA	Non-Precision Approach
NSE	Navigation System Error
PDOP	Position Dilution of precision
PR	Pseudo Range
PRN	Pseudo Random Noise
PSAC	Plan for Software Aspects of Certification
PHAC	Plan for Hardware Aspects of Certification

PVT	Position Velocity Time
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RMS	Root Mean Square
RNAV	Area Navigation
RNP	Required Navigation Performance
RSS	Root-Sum-Square
RTCA	Radio Technical Commission for Aeronautics
s	Second
SATCOM	Satellite Communications
SBAS	Satellite-Based Augmentation System
SDF	Simplified Directional Facility
SID	Standard Instrument Departure
SIF	Signal Integrity Flag
SISAI	Signal in Space Accuracy Indicator
SNR	Signal to Noise Ratio
SPS	Standard Positioning Service
sps	symbols per second
STAR	Standard Terminal Arrival Route
TAE	Track Angle Error
TSE	Total System Error
TSO	Technical Standards Order
TTFF	Time To First valid position Fix
UEE	User Equipment Error
UERE	User Equivalent Range Error
URA	User Range Accuracy
URE	User Range Error
UTC	Universal Time Coordinated
VDOP	Vertical Dilution of Precision
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
VORTA	VOR Co-located with TACAN
WGS-84	World Geodetic System 1984

(The English version is for reference only. In case of any discrepancy or ambiguity of meaning between this English translation and the Chinese version, the latter shall prevail.)