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Minimum Operational Performance Standards (MOPS) for GPS Local Area Augmentation System (LAAS) Airborne Equipment

RTCA DO-253C
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Prepared by: SC-159

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Foreword

This document was prepared by RTCA Special Committee 159 (SC-159) and approved by the RTCA Program Management Committee (PMC) on December 16, 2008.

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- Analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity, and efficiency;

- Developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of Minimum Operation Performance Standards (MOPS) for electronic systems and equipment that support aviation; and

- Assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU) and other appropriate international organizations can be based.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for airborne navigation equipment using the Global Positioning System (GPS) augmented by the Local Area Augmentation System (LAAS). These standards are partially derived from the requirements specified in RTCA DO-245(), *Minimum Aviation System Performance Standards (MASPS) for the Local Area Augmentation System (LAAS)*. Additional requirements have been derived by analysis of operational intent and direct allocation of performance requirements between airborne and ground systems. Throughout this document, the term "LAAS" is used as a generic reference to ground-based augmentation systems (GBAS) as defined by the International Civil Aviation Organization (ICAO), as the requirements in this standard are intended to comply with the ICAO Standards and Recommended Practices (SARPs) for the GBAS aircraft element.

Note: *At the time of this writing, the ICAO SARPs (through Amendment 82) have not been updated to include requirements for GBAS to support a type of service appropriate for conducting CAT II/III operations. Consequently, some requirements in this MOPS are beyond the requirements in the SARPs.*

The standards in this document define minimum performance requirements, functions and features for LAAS airborne equipment to support multiple types of service that are intended to support precision approach operations for all weather minimums. This standard also covers the computation and output of position, velocity, and time (PVT) to support area navigation and other applications.

Note: *The requirements for area navigation systems continue to evolve. Applicable standards include RTCA/DO-236(), RTCA/DO-229(), RTCA/DO-187() [as amended by TSO-C115()] and RTCA/DO-208() [as amended by TSO-C129()].*

Compliance with these standards by manufacturers, installers and users is recommended as a means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations.

The regulatory application of these standards is the responsibility of appropriate government agencies. In the United States, the Federal Aviation Administration (FAA) has published two Technical Standard Orders (TSO) for GPS/LAAS equipment, one for the LAAS VHF Data Broadcast (VDB) receiver function (TSO-C162) and another for the LAAS Position And Navigation (PAN) function (TSO-C161). The FAA plans to update these TSOs. These updated TSOs will continue to reflect the requirements in this MOPS consistent with supporting Category I approaches and the positioning service only. Requirements for Airborne Equipment Class D will be addressed by a subsequent TSO revision or an additional TSO after validation of these requirements.

The word "equipment", as used in this document, includes all components or units necessary (as determined by the equipment manufacturer or installer) to properly perform its intended function.

In this document, the term "shall" is used to indicate requirements. An approved design would comply with every requirement, which can be assured by inspection, test, analysis, or demonstration. The term "must" is used to identify items which are important but are either duplicated somewhere else in the document as a "shall", or are considered to be outside the scope of this document. The term "should" is used to denote a recommendation that would improve the LAAS equipment, but does not constitute a minimum requirement.

This document facilitates traceability by identifying each specific requirement with a requirement designator. The notation "*[LAAS-xxx]*", where xxx is a three-digit number, identifies each specific requirement for traceability purposes.

Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and forms the basis for the standards stated in Sections 2 through 4.

Section 2 contains the equipment performance requirements and test procedures for the VDB receiver function and the PAN function. These standards define required performance under standard operating conditions and stressed physical environmental conditions.

Section 3 describes those additional requirements and tests that ensure that the LAAS equipment performs its intended function in a particular installation. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the characteristics of installed LAAS equipment, and the expected pilot reactions to specified displays.

Appendix A contains a listing of abbreviations and definition of terms used in this document.

Appendix B lists requirements, by requirements number, that have changed from the prior version of this document. It also indicates requirements that have been added.

Appendix C contains an example of Final Approach Path and deviation calculations.

Appendix D defines the GPS interference environment for which the PAN equipment is required to operate.

Appendix E is reserved.

Appendix F is reserved.

Appendix G defines rotorcraft specific requirements for LAAS equipment.

Appendix H discusses test considerations.

Appendix I discusses GBAS Approach Service Types, Facility Classifications, Airborne Equipment Classifications, and Approach Facility Classifications.

Appendix J gives an example of how airborne geometry screening requirements can be derived based on ground monitor requirements and airplane performance for one airplane integration.

1.2 System Overview

The GPS/LAAS consists of three primary subsystems as shown in Figure 1-1:

a) The satellite subsystem, which produces ranging signals. This standard explicitly addresses the use of GPS and Satellite Based Augmentation System (SBAS) satellites.

b) The ground subsystem, which provides a VDB containing differential corrections and other pertinent information.

c) The airborne subsystem, which encompasses the aircraft equipment used to receive and process the GPS/LAAS signal in space in order to compute and output a position solution, deviations relative to a desired reference path, and appropriate annunciations.

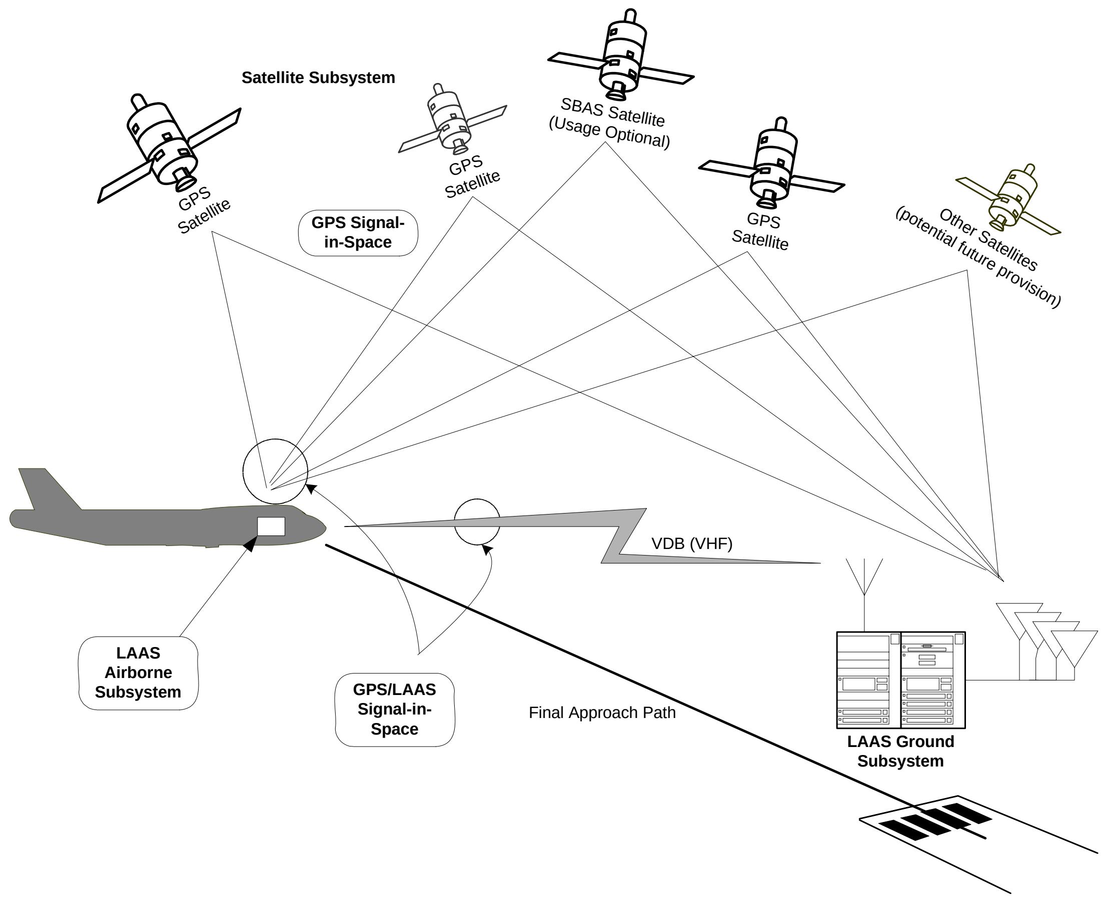


Figure 1-1 GPS/LAAS System

The GPS and SBAS satellites provide both the airborne subsystem and the ground subsystem with ranging signals. The ground subsystem produces ground-monitored differential corrections and integrity-related information as well as data including the definition of the final approach path, a geometric path-in-space to which the aircraft on approach will navigate. The final approach path is a straight line that extends indefinitely; other paths may be defined in the future.

These data are transmitted on a VDB to the airborne subsystem. The data and format of the data provided via the VDB are defined in RTCA/DO-246(), GNSS-Based Precision Approach Local Area Augmentation System (LAAS) Signal-in-Space Interface Control Document (ICD).

The airborne subsystem uses the GPS/LAAS signal in space to calculate a differentially corrected position estimate and generate deviation signals with respect to the final approach path. These deviations are formatted as angular measurements from reference surfaces similar to the deviations currently provided by ILS receivers. In addition, provisions have been made for rectilinear deviations, to support new and more advanced airplane integrations. The airborne subsystem also provides appropriate annunciation of system status and performance (e.g., alerts) and a position-velocity-time (PVT) output.

Note: *The interface for the minimum equipment is specified with angular deviations that are intended to mimic current ILS outputs. This is done to facilitate integration of LAAS equipment into existing airplanes with a minimum of disruption.*

1.3 Operational Goals

The operational goal of LAAS as specified in this document is to augment GPS to satisfy the requirements to support all categories of precision approach operations, area navigation in the terminal area, and automatic dependent surveillance. It is also anticipated that LAAS will support surface guidance and other operational needs in the future. This document will be updated if necessary as requirements to support these further operations are matured.

The LAAS signal provides the augmentation to GPS to obtain the required performance for the operations supported. The operations supported will be dependent on the user's equipment, the LAAS Ground Facility (LGF), and the capabilities of the airplane integration.

1.3.1 GBAS Approach Service Types

A GBAS ground station may provide multiple types of approach service simultaneously to many users who may have different operational objectives. To facilitate interoperability and consistent, predictable performance, the airborne and ground subsystem performance requirements are organized into matched sets that are intended to be used in conjunction. These matched sets of performance and functional requirements are referred to collectively as GBAS Approach Service Types (GAST). The specific requirements for the Ground and Airborne subsystems are then organized by Ground Facility Classifications (GFC) and Airborne Equipment Classifications (AEC). A discussion of the relationship between Approach Service Types and Facility Classifications is given in Appendix I. The requirements in this MOPS for such approaches are organized according to the AEC and/or by the GAST being supported by the equipment.

1.3.2 Notable Changes from Previous Version

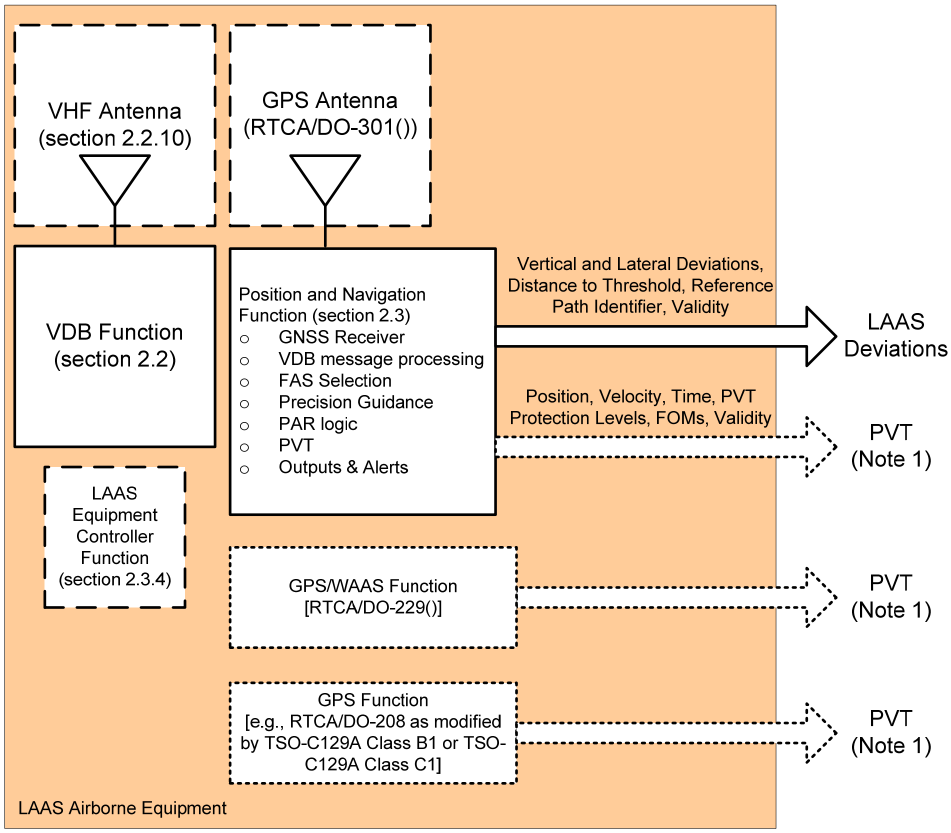
This version of the MOPS incorporates changes relative to DO-253B and previous versions that alter or augment the operational use of LAAS in some ways that are important to note:

- The GBAS maximum use distance (captured by the parameter Dmax) now only applies to the positioning service rather than for both the positioning and approach services. Operationally, this change allows for the pilot flying an approach to get feedback that the system is functioning properly at greater distances. The GBAS deviations may be observed by the pilot as soon as valid deviations can be calculated, generally expected to be 50-100 NM from the airport depending upon the aircraft altitude, the line-of-sight to the VDB transmitter, and the transmitted power. Service providers ensure the transmitted signal-in-space complies with the necessary requirements within a defined precision approach coverage region. Although similarly named, this region is different than the precision approach region (PAR) used by various functional requirements within this airborne receiver MOPS. The service provider's precision approach coverage volume must encompass all PARs associated with active approaches at an airport.
- The requirement to compute and output a vertical protection level for the positioning service has been eliminated. The horizontal protection level has been retained as a minimum output. This change was implemented to allow the maximum usable distance, Dmax, to be set to a much larger value.
- Velocity accuracy requirements and optional velocity figures of merit have been specified that will allow, for example, integration with position and velocity reporting applications.
- A new Approach Service Type was added and intended to support Category II/III operations. The service type includes several unique additional requirements and a different approach for allocation of performance between air and ground functions.
- VDB authentication protocols have been added as a required capability for avionics supporting the new Approach Service Type.
- GPS tracking constraints for receivers that use Double Delta delay lock loop discriminators have changed since last version.
- Airborne equipment classifications have been added as described in Section 1.3.1.

1.4 LAAS Airborne Equipment Functions

The functions provided by LAAS airborne equipment are shown in Figure 1-2. All LAAS equipment includes the VDB receiver function and the Position and Navigation (PAN) function. Up to three additional functions, all necessary at the aircraft system integration level, may be included within the LAAS equipment: the GPS antenna, the VHF antenna, and the LAAS equipment controller function. Requirements for the GPS antenna are defined in RTCA/DO-301(), *Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band*. If included within the LAAS equipment, the requirements for the VHF antenna and LAAS equipment controller function defined in Section 2.2.10 and Section 2.3.4, respectively, apply. This figure is shown for illustrative purposes only and is not intended to imply a requirement for a specific implementation, architecture, or design.

There is multiple LAAS ground system types defined in Section 1.5.6. The airborne equipment specified in this MOPS is interoperable with all types of LAAS ground systems.



Notes:

1. GPS/LAAS Airborne Equipment must provide at least one PVT output (reference section 2.1).

2. Optional LAAS airborne equipment function. Functions indicated as optional are only optional at the LAAS airborne equipment level and not at the aircraft level.

3. Either the GPS/WAAS [DO-229()] or an applicable RTCA GPS receiver MOPS-based standard [e.g., DO-208 as modified by TSO-C129A (Class B1 or C1)] since PVT outputs must be available when the equipment is not applying the LAAS differential corrections (reference section 2.1).

Figure 1-2 LAAS Airborne Equipment Functions

Shown in Figure 1-3 is a representative functional block diagram for the VDB receiver. This figure is shown for illustrative purposes only and is not intended to imply a specific implementation or design.

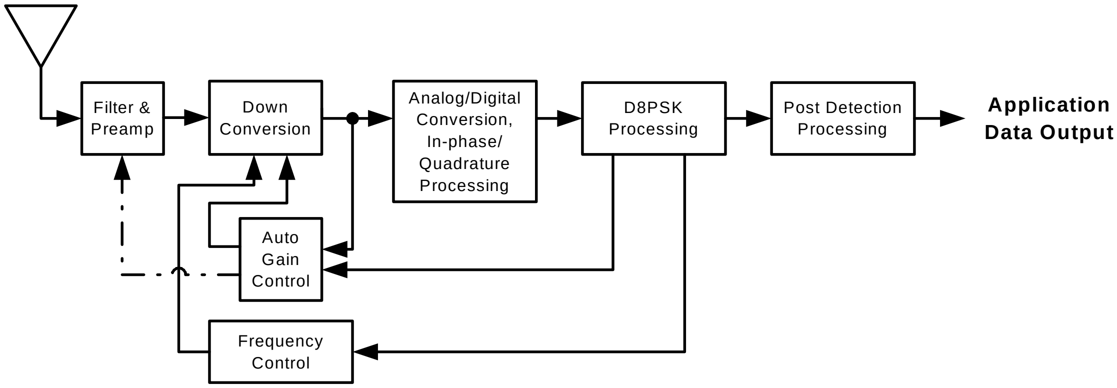


Figure 1-3 **VDB Receiver Functional Block Diagram**

1.5 Assumptions

Several assumptions have been made in developing this document and are identified below.

1.5.1 GPS Signal-in-Space

It is assumed that GPS satellites transmit signals that comply with the *GPS Standard Positioning Service (SPS) Performance Standard* (dated September 2008) and *Navstar GPS Space Segment / Navigation User Interfaces* [IS-GPS-200D with IRN-200D-001] (dated March 7, 2006).

1.5.2 SBAS Signal-in-Space

It is assumed that SBAS satellites transmit signals in accordance with Appendix A of RTCA/DO-229(), *Minimum Operational Performance Standards for GPS/WAAS Airborne Equipment*.

1.5.3 LAAS Signal-in-Space

It is assumed that the LAAS ground subsystem is providing a signal-in-space in accordance with RTCA/DO-246(), *GNSS Based Precision Approach LAAS Signal-In-Space Interface Control Document*.

1.5.4 GPS/LAAS Applications

Initially, it is envisioned that aircraft using the GPS/LAAS signal will maintain conformance to applicable approach and terminal instrument procedures, as well as current airway or other airspace separation requirements. Over time, it is anticipated that these requirements and procedures will be revised and/or extended to take greater advantage of the GPS/LAAS performance capabilities.

1.5.5 Applicability

The requirements of this document are applicable to GPS/LAAS equipment installed in aircraft.

1.5.6 LAAS Ground Subsystem

It is assumed that the LAAS ground subsystem is operating in conformance with the requirements stated in the ICAO Annex 10 Standards and Recommended Practices (SARPs). These standards were developed to support two types of services: precision approach services and a differentially corrected positioning service. The services provided by the ground subsystem are indicated by the Type 2 Message of the VHF data broadcast.

In addition, it is assumed that GAST D capable ground subsystems are operating in conformance with the requirements stated in the ICAO NSP CSG proposed SARPs revisions for GBAS GAST D.

Note: *At the time of this writing, the SARPs have not been modified to include the precision approach services beyond GAST C. Furthermore the SARPs refer to the various Service Types by a mixture of operational identifiers, e.g. CAT I and other terms such as "APV I" and "APV II". Amendments to support the GAST D requirements and terminology are being validated. Appendix I discusses how the organization of requirements for GASTs map into the requirements currently in the SARPs.*

The primary distinguishing feature between the two ground system services is the integrity level supported by the signal-in-space. The ground system that supports *only* approach services supports an integrity risk level of $2x10^{-7}$/approach; whereas a ground system that supports both approach services and the positioning service will support this per approach integrity and a positioning integrity risk level of 10^{-7}/hour.

For both types of services, the ground subsystem continuity requirement in the SARPs is that required to support CAT I operations. There may be additional continuity requirements imposed on some ground subsystems depending on the intended operations.

1.5.7 Interoperability

This document specifies a standard that will provide interoperability between LAAS signal-in-space and receiving LAAS equipment developed by different manufacturers. It is assumed that the signals-in-space for LAAS and WAAS are compliant with the ICAO SARPs for GBAS and SBAS, respectively.

1.5.8 RF Interference

It is assumed that the interference environment specified in Appendix D for which GPS/LAAS receivers must operate bounds the actual operational environment. If the interference environment is higher than that specified in Appendix D, the availability and continuity of LAAS will be reduced; however, there is no increase in the risk of misleading information (see section 2.3.6.9).

1.6 Test Considerations

The test procedures specified in Sections 2 through 4 are intended to be used as the recommended means of demonstrating compliance with the minimum acceptable performance parameters specified herein. Although specific test procedures are cited, it is recognized that other methods may be suitable. These alternate procedures may be used if they provide equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

1.6.1 Environmental Tests

Environmental tests are specified in Section 2.4. These tests, like bench test, are performed at the equipment level. The procedures and their associated limit requirements provide a laboratory means of determining the electrical and mechanical performance of the equipment under conditions expected to be encountered in actual aeronautical operations. Test results may be used by equipment manufacturers as design guidance, in preparation of installation instructions, and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.6.2 Bench Tests

The test procedures specified in Section 2.5 provide a means to demonstrate equipment performance in a simulated environment. Test results may be used as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.6.3 Installed Tests

The installed test procedures and their associated limit requirements are in Section 3. Although bench and environmental test procedures are not a part of installed tests, their successful completion is normally a precondition to the completion of the installed test. Installed tests are normally performed on the ground and in flight.

The test results may be used to demonstrate equipment functional performance in the environment in which it is intended to operate and with the minimum service to be provided.

1.7 Applicable Standards and Regulatory Documents

Note: *Document reference to "DO-xxx()" means to use the most current version of the referenced document. A reference to a specific document version means to use that version as a basis to understand this MOPS. Similar notation is applied to Advisory Circulars (AC) and Technical Standard Orders (TSO).*

FAA Advisory Circular (AC) 20-115B (this AC calls attention to RTCA/DO-178B).

FAA AC 20-138(), *Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment*.

FAA AC 25-11 *Transport Category Airplane Electronic Display Systems*, July 1987.

FAA AC 23.1309-1(), *Equipment, Systems, and Installations in Part 23 Airplanes*.

FAA AC 25.1309-1(), *System Design and Analysis*.

FAA AC 27-1(), *Certification of Normal Category Rotorcraft*.

FAA AC 29-2(), *Certification of Transport Category Rotorcraft*.

FAA E-2937A, *FAA Performance Type 1 LAAS Ground Facility Specification*.

Title 14 of the Code of Federal Air Regulations (14 CFR) § 23 and § 25.

Global Positioning System (GPS) Standard Positioning Service (SPS) Performance Standard, U.S. Department of Defense, Washington, DC, September 2008.

IS-GPS-200D, "Navstar GPS Space Segment / Navigation User Interfaces", with IRN-200D-001, dated March 7, 2006.

Guidelines for the Design of GPS and LORAN Receiver Controls and Displays, Huntley, M.S., 1995, DOT/FA/RD-95/1, DOT-VNTSC-FAA-95-7 (Huntley, 1995).

ICAO, Annex 10, International Standards and Recommended Practices for Aeronautical Telecommunications, Volume I, Radio Navigation Aids.

ICAO, World Geodetic System – 1984 (WGS-84) Manual (Doc 9674).

Military Standard 1472D, Human engineering design criteria for military systems, equipment, and facilities, 1989.

RTCA / DO-160F, Environmental Conditions and Test Procedures for Airborne Equipment.

RTCA / DO-178B (or later revision), Software Considerations in Airborne Systems and Equipment.

RTCA / DO-186A, Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating within the Radio Frequency Range 117.975-137.000 MHz, October 1995.

RTCA / DO-192, Minimum Operational Performance Standards for Airborne ILS Glideslope Receiving Equipment Operating within the Radio Range of 328.6 – 335.4 MHz, July 1986.

RTCA / DO-195, Minimum Operational Performance Standards for Airborne ILS Localizer Receiving Equipment Operating within the Radio Range of 108-112 Megahertz, November 1986.

RTCA / DO-196, Minimum Operational Performance Standards for Airborne VOR Receiving Equipment Operating within the Radio Frequency Range of 108-117.95 Megahertz, November 1986.

RTCA / DO-208, Minimum Operations Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System as amended by TSO-C129().

RTCA / DO-229D, Minimum Operational Performance Standards for GPS/WAAS Airborne Equipment.

RTCA / DO-235B, Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band.

RTCA / DO-236(), Minimum Aviation System Performance Standards, Required Navigation Performance for Area Navigation.

RTCA / DO-242(), Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B).

RTCA / DO-245A, Minimum Aviation System Performance Standards (MASPS) for the Local Area Augmentation System (LAAS).

RTCA / DO-246D, GNSS-Based Precision Approach Local Area Augmentation System (LAAS) Signal-in-Space Interface Control Document (ICD).

RTCA / DO-254(), Design Assurance Guidance for Airborne Electronic Hardware.

RTCA / DO-301(), Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band.

RTCA / DO-302(), Minimum Operational Performance Standards (MOPS) for Surveillance Transmit Processing (STP).

SAE Aerospace Recommended Practice 4102-4 Flight deck alerting systems (ARP 4102-4), July 1988.

SAE Aerospace Recommended Practice 4102-7 Electronic Displays (ARP-4102-7), July 1988.

SAE Aerospace Standard on Nomenclature and Abbreviations for Use on the Flight Deck SAE AS 425C), December 1985.

TSO-C36(), Technical Standard Order–C36, Airborne ILS Localizer Receiving Equipment.

TSO-C40(), Technical Standard Order–C40, VOR Receiving Equipment.

TSO-C129(), Technical Standard Order–C129, Airborne Supplemental Navigation Equipment using the Global Positioning System.

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2 Equipment Performance Requirements and Test Procedures

2.1 General GPS/LAAS Airborne Requirements

The requirements of this section apply to all GPS/LAAS airborne equipment.

The GPS/LAAS equipment shall *[LAAS-290]* output precision approach guidance under the conditions and in accordance with the requirements specified within this document.

The GPS/LAAS equipment shall *[LAAS-291]* output position, velocity, and time (PVT).

When the positioning service is supported and the distance (slant range) between the aircraft and the GBAS reference point is less than or equal to the maximum GBAS usable distance, Dmax, the PVT outputs of the LAAS airborne equipment shall *[LAAS-068]* meet the requirements of either: 1) Section 2.3 or 2) RTCA/DO-229() (any of the equipment classes), or 3) an applicable RTCA GPS receiver MOPS standard (e.g., RTCA/DO-208 as modified by TSO-C129A Class B1 or TSO-C129A Class C1).

When the positioning service is not supported, or when positioning service is supported and the distance (slant range) between the aircraft and the GBAS reference point is greater than the maximum GBAS usable distance, Dmax, the PVT outputs of the LAAS airborne equipment shall *[LAAS-069]* meet the requirements of either: 1) RTCA/DO-229() (any of the equipment classes), or 2) an applicable RTCA GPS receiver MOPS-based standard (e.g., RTCA/DO-208 as modified by TSO-C129A Class B1 or TSO-C129A Class C1). These output requirements are summarized in Table 2-1 below.

Table 2-1 GPS/LAAS Airborne Equipment Output Requirements

	DCPS Supported and Slant Range ≤ Dmax	**DCPS Not Supported or Slant Range > Dmax**
PVT Outputs	Either: 1. LAAS differential PVT as defined in Section 2.3, or 2. In accordance with DO-229(), or 3. In accordance with an applicable RTCA GPS receiver MOPS-based standard (e.g., DO-208 as modified by TSO-C129A Class B1 or TSO-C129A Class C1)	Either: 1. In accordance with DO-229(), or 2. In accordance with an applicable RTCA GPS receiver MOPS standard (e.g., DO-208 as modified by TSO-C129A Class B1 or TSO-C129A Class C1)

Note 1: *Only RTCA/DO-229() addresses the integration of precision approach with other area navigation functions. GNSS equipment that only meets the requirements of RTCA/DO-208 may be subject to operational restrictions due to the lack of compatibility with Required Navigation Performance (RNP) requirements.*

Note 2: Applications using ADS-B for surveillance require outputs in accordance with RTCA DO-242() and DO-302().

2.1.1 Airworthiness

The design and manufacture of the equipment shall *[LAAS-001]* support installation so as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall *[LAAS-002]* perform its intended function, as defined by this document and the manufacturer.

2.1.3 Fire Protection

All materials used shall *[LAAS-003]* be self-extinguishing, except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.

2.1.4 General Human Factors Requirements and Applicable Documents

If the GLS equipment is intended to contain the controller function (e.g., pilot interface), it shall *[LAAS-004]* comply with the requirements of this section.

Note: The requirements of this section are not intended to preclude the use of existing approvals for a control function or pilot interface existing outside this equipment that has been developed and certified under guidance of another TSO, Advisory Circular, or prior regulatory approvals. The requirements of this section are intended to provide an optional means for manufacturers to certify a GLS controller under this guidance.

Note: The requirements in this section are intended to provide a consistent application and interpretation of the human factors issues associated with developing equipment to be used for navigation. These requirements are intended to provide design guidance, and it is not implied that every "shall" must be specifically tested.

Guidelines for the design of the human factor aspects of controls displays and operating procedures are available in the following documents:

a) FAA-AC 25-11 Transport Category Airplane Electronic Display Systems (AC 25-11), July 1987.

b) SAE Aerospace Recommended Practice 4102-4 Flight deck alerting systems (ARP 4102-4), July 1988.

c) SAE Aerospace Recommended Practice 4102-7 Electronic Displays (ARP-4102-7), July 1988.

d) Military Standard 1472D, Human engineering design criteria for military systems, equipment, and facilities, 1989.

e) SAE Aerospace Standard on Nomenclature and Abbreviations for Use on the Flight Deck SAE AS 425C), December 1985.

f) Title 14, Code of Federal Regulations, part 25.1322 (14 CFR part 25.1322).

g) Guidelines for the Design of GPS and LORAN Receiver Controls and Displays, Huntley, M.S., 1995, DOT/FA/RD-95/1, DOT-VNTSC-FAA-95-7 (Huntley, 1995).

Note: *Relevant portions of the first three documents and others are reviewed and abstracted in (Huntley, 1995). This document also includes background information and additional relevant detail required for display and control design issues identified below.*

Controls and displays should be consistent with the referenced human factor guidelines of these documents. Controls and displays should be designed to maximize operational suitability, minimize pilot workload, and minimize the possibility of human error associated with equipment operations. Maintaining situational awareness is a key factor in catching errors.

2.1.4.1 Operation of Controls

The equipment shall *[LAAS-005]* be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence which would result in a condition detrimental to the equipment or operation of the aircraft. The design and operation of controls should be consistent with the principles and specifics presented in the above documents.

2.1.4.2 Accessibility of Controls

Controls that are normally adjusted in flight shall *[LAAS-006]* be accessible without interfering with the visibility of critical displays. Controls shall *[LAAS-007]* provide clear tactile or visual feedback when operated. The controls shall *[LAAS-008]* be movable without excessive effort and detents shall *[LAAS-009]* be well defined. Control spacing, physical size, and control logic shall *[LAAS-010]* be sufficient to avoid inadvertent activation. Controls shall *[LAAS-011]* be operable with the use of only one hand.

Controls that do not require adjustment during flight shall *[LAAS-012]* not be readily accessible to flight personnel.

2.1.4.3 Control Labels

Labels shall *[LAAS-013]* be readable from viewing distances of 30 inches, under anticipated lighting conditions. Labels should be unobstructed by controls when viewed within the angle of regard, and located next to or on the controls that they reference. Label placement should follow a consistent logic. Terminology for labeling should describe the function of the control in meaningful terms. Terms should be consistent with those on the display of the function or mode selected and spelled out whenever possible.

2.1.4.4 Equipment Operating Procedures

Equipment operating procedures should be designed to maximize operational suitability, minimize pilot workload, and minimize reliance on pilot memory. Detectability of operating errors should be maximized. The actions required to recover from errors should be intuitive, quick, and with minimum impact on subsequent operations. Where possible, maximum use of prompting should be used to minimize reliance on pilot memory.

Operating rules and use of controls required to implement equipment functions should be consistent from mode to mode.

Use of prompting cues shall *[LAAS-014]* be consistent. For example, if used as such a cue, illumination of controls would always indicate that the illuminated control should be used next.

2.1.4.5 Minimum Workload Functions

Operations that occur regularly or are conducted under potentially stressful operating conditions (e.g., missed approaches) must be possible with a small number of control operations. The number of operations may be minimized through the use of dedicated controls, anticipation of pilot requirements, and the use of quick-access menus designed to facilitate rapid selection of required navigation functions (e.g., direct flight to a waypoint and returning to the final approach course after a missed approach). During flight, selection or activation of a function shall *[LAAS-015]* not require simultaneous use of two or more controls (e.g., pushing two buttons at once). If a keypad is included in the design, it should permit single-handed data entry with a layout that enhances both the accuracy and speed of data input. Where multiple actions are necessary to accomplish a function, the equipment should provide contextual information of the active sub-function or mode (e.g., NAV, FPL).

The task of selecting an approach (reference Section 2.3.4) shall *[LAAS-016]* be capable of being accomplished within the recommended maximum number of five actions and with less than 10 seconds to accomplish the task (as a bench test without distraction). Both the time and number of actions are worst-case, regardless of where the function is initiated (i.e., the pilot may be in the middle of doing something else before initiating the function). An action is defined as a discrete action: e.g., a single button push or a continuous turn of a knob, even if the knob must be turned multiple times. It is acceptable to exceed the maximum number of actions, provided the particular actions required are easy to accomplish and result in a comparable pilot workload (e.g., repeated button pushes of the same button).

2.1.4.6 Displays

Note: Additional information on electronic displays can be found in AC-25-11.

2.1.4.6.1 Discriminability

Alert, alarms and symbols shall *[LAAS-017]* be distinctive and discriminable from one another. If a control is used to perform multiple functions, the functionality shall *[LAAS-018]* be clearly distinguished. There should be a clear indication when any control is in an altered state and not the default (e.g., if a knob is pulled out and functions differently). Fields that are editable, selectable, or require operator entry should be clearly denoted.

The equipment should provide an indication when additional information (e.g., pages) is available.

2.1.4.6.2 Brightness, Contrast, and Color

Displays shall *[LAAS-019]* be readable, and colors shall *[LAAS-020]* be discriminable under anticipated lighting conditions. Reflectance of the display should be minimal. Aviation conventions should be observed when using colors for coding. Color coding of safety-critical information should be accompanied with another distinguishing characteristic such as shape or location. No more than five colors should be used on the display. When color is used to distinguish between functions and indications, red shall *[LAAS-021]* not be used other than for warning indications (hazards which may require immediate corrective action). Amber (yellow) shall *[LAAS-022]* be reserved for caution indicators. Blue should be avoided because it is difficult for the human eye to bring blue symbols into focus and to distinguish the color from yellow when the symbols are small. (Ref. AC 25-11 for generally accepted aviation practices.)

2.1.4.6.3 Angle of Regard

All displays shall *[LAAS-023]* be fully readable up to a horizontal viewing angle of 35 degrees from normal to the face of the display screen. They shall *[LAAS-024]* be fully readable up to a vertical viewing angle of 20 degrees from normal to the face of the display screen. This angle of regard does not ensure that the equipment may be installed in any aircraft; it is recommended that the angle of regard be maximized to increase the flexibility of the equipment for installation.

2.1.4.6.4 Symbology

Displays should use characteristics and symbols similar to those shown on published charts and sectionals or with commonly accepted aviation practices. The potential for misinterpreting symbols should be minimized. Symbols used for one purpose on published charts should not be used for another purpose on the equipment display. Guidelines for electronic display symbology are provided in SAE ARP 4102-7.

2.1.4.6.5 Alphanumerics

Display of letters and numbers depicting primary data shall *[LAAS-025]* be readable from viewing distances of 30 inches under anticipated lighting. The required size may depend upon the display technology used. Initial guidelines for symbol sizes for the indicated categories of information are:

0.18” for primary data

0.12” for secondary data

0.09” for legends

Note: Installation restrictions may be used to compensate for limitations of display designs.

2.1.4.7 Annunciations

Visual annunciations shall *[LAAS-026]* be consistent with the criticality of the annunciation and shall *[LAAS-027]* be readable under all cockpit illumination conditions. Visual annunciations shall *[LAAS-028]* not be so bright or startling as to reduce pilot dark adaptation. The use of colors to code annunciations should follow color conventions described in AC 25-11, SAE ARP 4102-4, and 14 CFR, part 25.1322.

Auditory alerts have the advantage of being useful regardless of the pilots head and eye orientation, but their use with GPS/LAAS equipment should be considered with care to avoid compromising other auditory alerts that may be available in the cockpit. Application of such alerts should be consistent with ARP 4102-4 and adaptable to the annunciator philosophy of the aircraft. Auditory alerts should not be used as the sole source of information, but to draw the pilot's attention to information on a visual display, and they should be detectable by the pilot when wearing a headset.

Warnings, annunciations, and messages not critical to the safety of instrument approaches or missed approaches should be suppressed during those phases of terminal operations.

2.1.4.7.1 Annunciators

A simple font should be used for all alphanumerics. Characters used on alert and status indications should be of the size and brightness necessary to be readable without error or strain under anticipated lighting conditions. Brightness shall *[LAAS-029]* be controllable, which does not preclude automatic adjustment. The equipment shall *[LAAS-030]* provide the capability to test all external annunciators.

2.1.4.7.2 Pilot Indications

Pilot indications should be grouped by level of urgency. Each group of indications should be ordered chronologically. From each grouping, any current pilot indications shall *[LAAS-031]* be accessible by the pilot.

2.1.5 Effects of Test

The equipment shall *[LAAS-032]* be designed so that the application of specified test procedures is not destructive or does not degrade equipment performance following the application of these tests, except as specifically allowed in this MOPS.

2.2 VHF Data Broadcast (VDB) Receiver Subsystem

2.2.1 General Requirements

The requirements specified in this section shall *[LAAS-033]* be achieved when the VDB receiver subsystem is operating in the presence of the Standard VDB

Test Signal (as specified in Section 2.5.2.1.1) at the applicable specified power level.

All power levels specified for the VDB are measured as the average power over the period of the synchronization and ambiguity resolution portion of the message at the receiver input port. All power levels specified for other emissions (i.e., VHF Omnirange (VOR), Instrument Landing System (ILS) localizer and Frequency Modulation (FM) broadcast) are measured as the power in the Radio Frequency (RF) carrier at the receiver input port.

Note: *See Figure 1-3 for a representative block diagram.*

Note: *Determination of the Message Failure Rate (MFR) requires additional test equipment to verify the Cyclic Redundancy Check (CRC), as the CRC is not verified by the VDB receiver function. Instead, it is verified by the PAN function to reduce the hazard classification of the VDB receiver.*

2.2.1.1 Design Assurance

The hardware and software shall *[LAAS-034]* be designed and developed such that the probability of providing misleading information (MI) and the probability of loss of function are acceptable based on the system integrity and continuity requirements, respectively. This requirement must be met when the equipment is in its installed configuration for the most stringent operation supported. To demonstrate compliance, it will be necessary to conduct a safety assessment to evaluate the system's implementation against known failure conditions. This safety assessment should be based upon the guidance of AC 23.1309-1() for Part 23 aircraft, AC 25.1309-1() for Part 25 aircraft, AC 27-1() for normal category rotorcraft, and AC 29-2() for transport category rotorcraft.

2.2.1.1.1 Hardware

An acceptable means to demonstrate integrity compliance for the VDB receiver is to show that no failure of the equipment can result in misleading information (MI). This may be accomplished by integration with a PAN that a) provides the capability for the pilot to independently verify that the correct approach is selected, and b) verifies the LAAS message CRC.

Demonstration of compliance with the continuity requirements depends on the required probability of a detected failure. The required probability will depend on the level of airborne redundancy. Hardware design assessment must consider the MTBF of the equipment as well as the independence of failure modes for redundant equipment.

2.2.1.1.2 Software

FAA Advisory Circular (AC) 20-115B, which references RTCA/DO-178B, provides an acceptable means for showing that software complies with applicable airworthiness requirements. One acceptable means to demonstrate integrity compliance for the VDB receiver is to show that no design failure of the equipment can result in misleading information, and to develop all software that affects VDB functions to at least Level D criteria. Another acceptable approach is to substantiate software levels required based on a system safety assessment.

Note: *Demonstration of compliance with the continuity requirements depends on the required probability of a detected failure. The required probability will depend on the level of airborne equipment redundancy. For applications beyond CAT I, (e.g., autoland), software development of level D classification may not be sufficient to ensure the probability of detected failure is low enough such that system continuity requirements are met. Furthermore, most redundancy methods rely on failures in redundant architectures to be independent. Software level D classification may not be sufficient to ensure independence of detected failures. Software development levels required should be determined based on a system continuity assessment. Software level A is recommended for equipment expected to support autoland.*

2.2.2 Tuning

2.2.2.1 Frequency Range

The VDB receiver subsystem shall *[LAAS-035]* be capable of tuning frequencies in the range of 108.000 MHz to 117.975 MHz in increments of 25 kHz.

Note: *In accordance with ICAO Annex 10, operational frequency assignments will be assigned on 25 kHz centers in the range from 108.025 MHz to 117.950 MHz inclusive.*

2.2.2.2 Frequency Selection

The VDB receiver subsystem shall *[LAAS-036]* accept input of either a VDB frequency or a LAAS channel number. If it accepts input of the LAAS channel number (N), it shall *[LAAS-037]* convert it to a VDB frequency (F) using the equation given in Section 2.3.5.

Selection of a LAAS channel number shall *[LAAS-038]* not result in the VDB receiver subsystem tuning to frequencies outside of the range 108.000 to 117.975 MHz.

2.2.2.3 Response Time

The VDB receiver subsystem shall *[LAAS-039]* output the LAAS messages from the new frequency within 3 seconds of receipt of the command to change to that frequency.

2.2.3 Data Latency

The VDB receiver subsystem shall *[LAAS-040]* output all bits of a desired LAAS message within 125 milliseconds of the arrival of the last bit of that message at the VDB antenna.

Note: *The data latency only applies after the VDB is providing messages as specified in Section 2.2.2.3.*

2.2.4 Data Format Decoding

The VDB receiver subsystem shall *[LAAS-041]* properly demodulate and decode the VHF data broadcast signal specified in DO-246().

2.2.5 Message Failure Rate

The VDB receiver subsystem shall *[LAAS-042]* achieve a message failure rate (MFR) less than or equal to one failed message per 1000 full-length (222 bytes) application data messages while operating over an input power range between S_{min} = –87 dBm and S_{max} = –1 dBm, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed ΔS_{max} = 40 dB.

Note: *The VDB field strength has been specified to achieve a minimum signal power at the receiver of S_{min}, as shown in the VDB Link Budget given in RTCA DO-245A.*

Note: *Successive bursts are defined as consecutive, scheduled bursts from a ground transmitter. The ground system transmitter broadcasts a burst in at least every fifth consecutive frame for each assigned time slot being used.*

Note: *This requirement includes the condition of the received power in consecutive slots in a given frame varying from S_{min} to S_{max}.*

While operating over an input power range between S_{min} and S_{max}, if the average received signal power variation between successive frames in a given time slot exceeds ΔS_{max}, the MFR shall *[LAAS-051]* not exceed 60%.

The message failure rate (MFR) is defined as the total number of messages lost by the VDB receiver subsystem plus those messages which do not pass the cyclic redundancy check (CRC) after application of the forward error correction, divided by the total number of messages sent by the ground subsystem.

2.2.6 VDB Signal Tracking Requirements

2.2.6.1 Carrier Frequency Capture Range

The VDB receiver subsystem shall *[LAAS-045]* acquire and maintain lock on signals with a frequency offset of up to ±418 Hz from the nominal assigned frequency.

Note: *The frequency stability of the LAAS ground subsystem (±236 Hz at 117.975 MHz), and the worst-case Doppler shift due to the motion of the aircraft (±182 Hz at 900 knots), are reflected in the above requirement. The dynamic range of the automatic frequency control (AFC) should also consider the frequency-stability error budget of the airborne VDB receiver subsystem itself.*

2.2.6.2 Carrier Frequency Slew Rate

The VDB receiver subsystem shall *[LAAS-046]* acquire and maintain lock on signals when the received carrier frequency is varied within the range specified in Section 2.2.6.1 at a rate of 15 Hz per second.

Note: *This assumes ±0.1 PPM/second frequency drift for the VDB transmitter and ±0.03 PPM/second frequency drift due to Doppler changes when the aircraft is subjected to 1g acceleration at 117.975 MHz.*

2.2.6.3 Symbol Rate Tolerance

The VDB receiver subsystem shall *[LAAS-047]* acquire and maintain lock on signals for received symbol rates between 10499.45 and 10500.55 symbols per second.

Note: *This includes ±50 PPM for the transmitter symbol rate tolerance and ±1.5 PPM for aircraft Doppler at 900 knots. This totals ±51.5 PPM.*

2.2.7 Co-Channel Rejection

2.2.7.1 VDB as the Undesired Signal

The VDB receiver subsystem shall *[LAAS-052]* meet the requirements specified in Section 2.2.5 in the presence of an undesired co-channel VDB signal that is either:

a) assigned to the same time slot(s) and whose power level is 26 dB below the desired VDB power level; or

b) assigned different time slot(s) and whose power is up to +15 dBm at the receiver input.

2.2.7.2 VOR as the Undesired Signal

The VDB receiver subsystem shall *[LAAS-053]* meet the requirements specified in Section 2.2.5 in the presence of an undesired co-channel VOR signal whose power level is 26 dB below the desired VDB power level.

2.2.7.3 ILS Localizer as the Undesired Signal

The VDB receiver subsystem shall *[LAAS-054]* meet the requirements specified in Section 2.2.5 in the presence of an undesired co-channel ILS localizer signal whose power level is 26 dB below the desired VDB power level.

2.2.8 Adjacent Channel Rejection

2.2.8.1 1st Adjacent 25 kHz Channels (±25 kHz)

The VDB receiver subsystem shall *[LAAS-055]* meet the requirements specified in Section 2.2.5 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel whose power level is either:

a) 18 dB above the desired VDB power level when the undesired signal is another VDB signal assigned to the same time slot(s); or

b) Equal to the desired VDB power level when the undesired signal is a VOR; or

c) Equal to the desired VDB power level when the undesired signal is an ILS localizer.

2.2.8.2 2nd Adjacent 25 kHz Channels (±50 kHz)

The VDB receiver subsystem shall *[LAAS-056]* meet the requirements specified in Section 2.2.5 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel whose power level is either:

a) 43 dB above the desired VDB power level when the undesired signal is another VDB source assigned to the same time slot(s); or

b) 34 dB above the desired VDB power level when the undesired signal is a VOR; or

c) 34 dB above the desired VDB power level when the undesired signal is an ILS localizer.

2.2.8.3 3rd Adjacent 25 kHz Channels (±75 kHz) and Beyond

The VDB receiver subsystem shall *[LAAS-057]* meet the requirements specified in Section 2.2.5 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel whose power level is either:

a) 46 dB above the desired VDB power level when the undesired signal is another VDB source assigned to the same time slot(s); or

b) 46 dB above the desired VDB power level when the undesired signal is a VOR; or

c) 46 dB above the desired VDB power level when the undesired signal is an ILS localizer.

Note: *With no on-channel VDB signal present, the VDB receiver subsystem should not output data from an undesired VDB signal on any other assignable channel.*

2.2.9 Out-of-Band Rejection

2.2.9.1 VDB Interference Immunity

The VDB receiver subsystem shall *[LAAS-058]* meet the requirements specified in Section 2.2.5 in the presence of one or more signals having the frequency and total interference levels shown in Table 2-2.

Table 2-2 Frequency and Power of Undesired Signals

Frequency	Maximum Level of Undesired Signal at the Receiver Input (dBm)
50 kHz up to 88 MHz	-13
88 MHz to 107.900 MHz	VHF FM Broadcast (See Section 2.2.9.2.)
108.000 MHz to 117.975 MHz	Excluded
118.000 MHz	-44
118.025 MHz	-41
118.050 MHz up to 1660.5 MHz	-13

Note: The relationship is linear between adjacent points designated by the above frequencies.

2.2.9.2 FM Immunity

2.2.9.2.1 Desensitization

The VDB receiver subsystem shall *[LAAS-269]* meet the requirements of Section 2.2.5 in the presence of VHF FM broadcast signals with signal levels shown in Table 2-3 and Table 2-4.

Table 2-3 Desensitization Frequency and Power Requirements That Apply for VDB Frequencies 108.000 to 111.975 MHz

Frequency	Maximum Level of Undesired Signals at the Receiver Input (dBm)
88 MHz ≤ f ≤ 102 MHz	+15
104 MHz	+10
106 MHz	+5
107.9 MHz	-10

Note 1: The relationship is linear between adjacent points designated by the above frequencies.

Note 2: This desensitization requirement does not apply to channels 108.000, 108.025 and 108.050 MHz for FM carriers above 107.7 MHz.

Table 2-4 Desensitization Frequency and Power Requirements That Apply for VDB Frequencies 112.000 to 117.950 MHz

Frequency	Maximum Level of Undesired Signals at the Receiver Input (dBm)
88 MHz ≤ f ≤ 104 MHz	+15
106 MHz	+10
107 MHz	+5
107.9 MHz	0

Note: *The relationship is linear between adjacent points designated by the above frequencies.*

2.2.9.2.2 Intermodulation Rejection

The VDB receiver subsystem shall *[LAAS-059]* meet the requirements of Section 2.2.5 in the presence of interference from third order intermodulation products from two VHF frequency modulated (FM) broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 72 \le 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108 MHz and

$$2N_1 + N_2 + 3\left(24 - 20\log\frac{\Delta f}{0.4}\right) \le 0$$

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VDB receiver input where neither level exceeds the desensitization criteria set forth in Section 2.2.9.2.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

The equal-level, two-signal inter-modulation requirement is depicted in Figure 2-1.

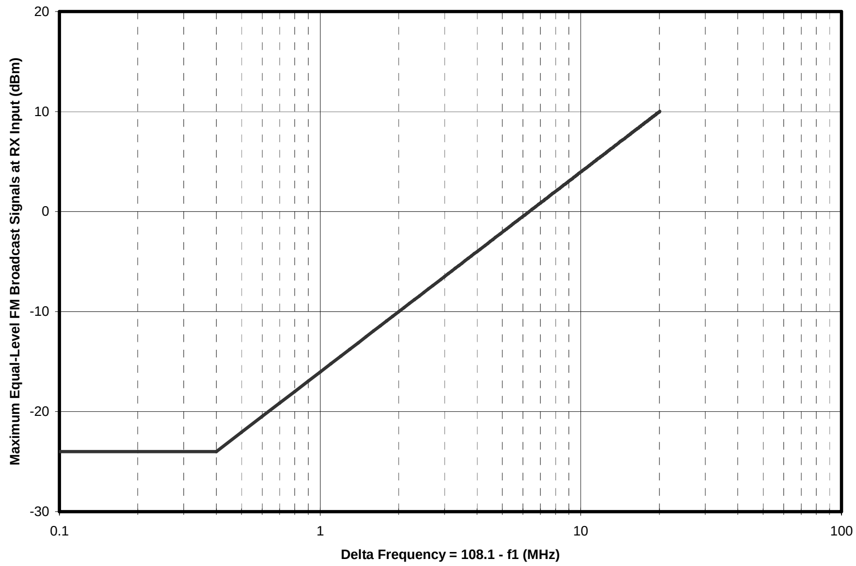


Figure 2-1 **Maximum Tolerable Equal-Level FM Broadcast Signals**

2.2.9.3 Burn Out Protection

The VDB receiver subsystem shall *[LAAS-060]* survive the application of a +20 dBm signal at the receiver input without damage throughout the frequency range of 50 kHz to 1660.5 MHz.

2.2.10 Receiver-to-Antenna Interface

2.2.10.1 Receiver Voltage Standing Wave Ratio (VSWR)

The VSWR at the receiver input terminal shall *[LAAS-061]* not exceed 4:1 on any selectable channel.

2.2.10.2 Antenna Characteristics

The requirements in this section apply to VDB antennas included as part of the VDB equipment. The VDB antenna requirements for horizontally polarized antennas are contained in Section 2.2.10.2.1 and the requirements for vertically polarized antennas are contained in Section 2.2.10.2.2.

Note 1: *The following requirements are not intended to preclude the use of existing antennas previously approved under other RTCA MOPS requirements (and associated TSO certifications) or prior regulatory approvals. This includes, but is not limited to, antennas approved under TSO-C36(), Airborne ILS Localizer Receiving Equipment or TSO-C40(), VOR Receiving Equipment.*

Note 2: *Refer to Section 3.12 for rejection of out-of-band signals by the installed VDB antenna.*

2.2.10.2.1 Horizontally Polarized Antenna Characteristics

Note: *The antenna requirements in this section are consistent with those requirements in RTCA/DO-196, MOPS for Airborne VOR Receiving Equipment Operating Within the Radio Frequency Range of 108-117.95 MHz, November 1986.*

2.2.10.2.1.1 Horizontal Antenna Gain

a) Over the frequency range 108.000 to 117.975 MHz, the reception of the horizontally polarized component of radiated signals in the horizontal plane from the forward and rearward directions shall *[LAAS-062]* not be down more than 10 dB when compared to the maximum output response of a standard horizontal dipole antenna which is resonant at 113.000 MHz and mounted 25.4 cm (10 inches) above the ground plane.

b) At any frequency within 108.000 to 117.975 MHz, the difference between the maximum and the minimum reception of the horizontally polarized component of radiated signals from any direction in the horizontal plane shall *[LAAS-063]* not exceed 20 dB.

2.2.10.2.1.2 Horizontal Antenna VSWR

When the antenna to be used with the receiver is designed for use with a transmission line, over the frequency range of 108.000 to 117.975 MHz, the VSWR produced on the antenna transmission line by the antenna shall *[LAAS-064]* not exceed 6:1.

2.2.10.2.2 Vertically Polarized Antenna Characteristics

Note: *The antenna requirements in this section are consistent with those requirements in RTCA/DO-186A, MOPS for Airborne Radio Communications Equipment Operating Within the Radio Frequency Range of 117.975-137.000 MHz, October 1995.*

Note: *VHF air-ground communication systems operate with vertically polarized antennas. VDB installations also utilizing vertically polarized antennas will not be able to realize the approximately 15 dB of cross-polarization rejection afforded VDB installations utilizing horizontally polarized antennas. This will necessitate additional isolation from other sources which may not be achievable on certain aircraft.*

2.2.10.2.2.1 Vertical Antenna Gain

a) Over the frequency range of 108.000 to 117.975 MHz, when the antenna is mounted on a 4' x 4' (or larger) ground plane, the reception of the vertically polarized component of a radiated signal in the horizontal azimuth plane shall *[LAAS-065]* not be down more than 6 dB when compared to a standard vertically polarized monopole antenna.

b) At any frequency within 108.000 to 117.975 MHz, when the antenna is mounted on a 4' x 4' (or larger) ground plane, the difference between the maximum and the minimum reception of the vertically polarized component of radiated signals from any directions in the horizontal azimuth plane shall *[LAAS-066]* not exceed 6 dB.

2.2.10.2.2.2 Vertical Antenna VSWR

Over the frequency range of 108.000 to 117.975 MHz, when the antenna is mounted on a 4’ x 4’ (or larger) ground plane, the VSWR produced on the antenna transmission line by the antenna shall *[LAAS-067]* not exceed 3:1.

2.3 Position and Navigation (PAN) Subsystem

2.3.1 General

The PAN equipment receives the LAAS messages that include differential corrections. The differential corrections are added to the ranging measurements and used to compute a highly accurate navigation solution with high integrity. The PAN equipment also receives approach data from the LAAS messages and makes a selection based on the pilot’s request. From this information, the PAN equipment computes guidance for the approach that has been selected.

2.3.2 Design Assurance

The hardware and software shall *[LAAS-070]* be designed and developed such that the probability of providing misleading information and the probability of loss of function are acceptable based on the system integrity and continuity requirements, respectively. This requirement must be met when the equipment is in its installed configuration for the most stringent operation supported. To demonstrate compliance, it will be necessary to conduct a safety assessment to evaluate the system’s implementation against known failure conditions. This safety assessment should be based upon the criteria of AC 23.1309-1() for Part 23 aircraft, and AC 25.1309-1() for Part 25 aircraft, AC 27-1() for normal category rotorcraft, and AC 29-2() for transport category rotorcraft.

Note: *Failure conditions of GPS/LAAS that cause out-of-tolerance error conditions during a CAT I approach, without identifying the data as invalid, can be classified as hazardous/severe-major. Failure conditions of GPS/LAAS that cause out-of-tolerance error conditions during a CAT III approach, without identifying the data as invalid, should either be extremely improbable or should not prevent a safe landing or go-around.*

2.3.2.1 Hardware

An acceptable means to demonstrate integrity compliance for PAN equipment is to show that failures of the equipment that result in misleading information are not more probable than half of the aircraft integrity requirement for the most stringent operation and aircraft supported (as defined in AC 23-1309-1() for Part 23 aircraft, the aircraft integrity requirement depends upon the aircraft type).

Note: *The aircraft level requirement can be allocated to the different systems that can generate misleading information. It is assumed that the majority of aircraft installations can be supported by the allocation of half of the integrity requirement to the LAAS airborne equipment. To* *support some aircraft installations, it may be necessary to meet a more stringent allocation.*

For complex firmware implementations such as Application-Specific Integrated Circuits (ASICs), development processes similar to those described in RTCA/DO-178B (or appropriate revisions) or RTCA/DO-254() provide an acceptable means of compliance with applicable airworthiness requirements.

2.3.2.2 Software

AC20-115B, which references RTCA/DO-178B, provides an acceptable means for showing that software complies with applicable airworthiness requirements.

2.3.3 Interference and Dynamics Environment

Unless otherwise stated, the requirements of Section 2.3 shall *[LAAS-071]* be met under the interference environment defined in Appendix D and under the normal aircraft dynamics defined by the maximum values shown in Table 2-5.

Table 2-5 Normal Maneuvers Maximum Values

LAAS Equipment Outputs	Ground Speed	Horizontal Acceleration	Vertical Acceleration	Total Jerk
Precision Approach Guidance	250 kts	0.58 g	0.50 g	0.25 g/s
PVT	800 kts	0.58 g	0.50 g	0.25 g/s

Note: *g = acceleration of gravity, i.e., 9.8 m/s^2.*

2.3.4 Approach and Reference Station Selection

If the PAN includes a pilot interface for selecting the LAAS channel, then it shall *[LAAS-072]* allow selection of a channel in the range 20001 to 39999.

If the PAN does not include a pilot interface for the LAAS channel number, then the PAN shall *[LAAS-073]* accept input of the 5-digit channel or accept input of a Reference Path Data Selector (RPDS) and a Reference Station Data Selector (RSDS).

Note: *The PAN requirements have been developed to support two different approach selection methods and a number of different avionics architectures. A control head to select a LAAS channel number will be included in the PAN or will interface with the PAN, and the PAN may interface with a control head that allows the pilot to select the approach using the airport, runway number and letter, and route indicator. It is expected that aircraft will provide access to both methods of tuning (e.g., through a separate control head or through a Flight Management System).*

Note: *The control head may also allow selection of channels or frequencies to support ILS, MLS, and SBAS.*

2.3.5 Reference Data Selectors and Frequency Mapping

If the PAN converts the LAAS channel number (N) to an RPDS or a RSDS, it shall *[LAAS-074]* be determined as follows:

RPDS or RSDS = (N-20000) div 411

where: x div y = k, the integer part of the quotient x/y

If the PAN converts the LAAS channel number (N) to a VDB frequency (F), it shall *[LAAS-075]* determine the frequency as follows:

F (MHz) = 108.000 + ((N-20000) mod 411)*0.025

where: x mod y = x – (x div y)*y

<u>Notes</u>: *1) The value of 411 was selected to ensure that channel numbers for approaches served by the same ground system have at least two unique digits, to reduce the likelihood of inadvertent selection of the wrong approach. N is in the range 20001 to 39999. Values of N, where ((N-20000) mod 411) > 399, are unusable because they map to frequencies above 117.975 MHz.*

2) The LAAS channel numbers allow for up to 49 RPDS/RSDS identifier "k" values (i.e., k = 0 to 48) for frequencies from 108.025 MHz to 114.775 MHz and for up to 48 RPDS/RSDS identifier "k" values (i.e., k = 0 to 47) for frequencies from 114.800 MHz to 117.950 MHz.

3) Some values of N map to the frequencies 108.000 and 117.975 MHz which are not included in the ICAO Annex 10 assignable frequency range.

2.3.6 GNSS Receiver Function

2.3.6.1 Ranging Sources

The PAN equipment shall *[LAAS-076]* automatically select ranging sources for use in the navigational computation. The PAN shall *[LAAS-268]* be capable of using GPS satellites. The use of SBAS satellites is optional.

LAAS AEC C equipment shall *[LAAS-077]* be capable of simultaneously tracking and continuously decoding the associated navigation data for at least 10 GPS ranging sources.

LAAS AEC D equipment shall *[LAAS-318]* be capable of simultaneously tracking and continuously decoding the associated navigation data for at least 12 GPS ranging sources.

LAAS equipment when supporting GAST C or the positioning service shall *[LAAS-316]* select the set of GPS satellites for use in the navigation computation from those that are above a 5 degree mask angle as follows: a) if there are 10 or fewer GPS satellites, then select all of them, b) if there are more than 10 GPS satellites, then select a subset of no fewer than 10.

Note: Mask angle is defined in Appendix A. Requirement number LAAS-316 was specified in this MOPS to improve the likelihood of selecting a common set of satellites among the ground and airborne LAAS equipment.

Note: LAAS equipment when supporting GAST D determines the satellite geometry that is acceptable. This is in contrast to LAAS equipment when supporting GAST C for which the ground subsystem relies on the satellite selection criteria above to meet aircraft position integrity requirements. If the positioning service is being supported in addition to GAST D, then the satellite selection criteria above should be used to generate the positioning service position solution.

2.3.6.2 Sensitivity and Dynamic Range

This MOPS defines one equipment architecture with respect to an active antenna that includes a preamplifier as shown in Figure 2-2.

Minimum requirements for a minimum standard active antenna are defined in RTCA/DO-301. Manufacturers that restrict their sensor interoperability to a specific antenna can use the unique characteristics of their active antenna in defining the sensitivity and dynamic range (and associated test conditions) as described in this document. All antennas shall *[LAAS-293]* comply with RTCA/DO-301, and to the extent non-standard antenna performance is used to define the equipment requirements, that performance shall *[LAAS-294]* be validated in accordance with the tests and methods described in RTCA/DO-301.

Throughout this section (and the test procedures), signal and interference power levels are specified at the input to the preamplifier (antenna port in Figure 2-2) unless otherwise stated. The manufacturer must specify the minimum and maximum preamplifier gain (minimum gain is specified in RTCA/DO-301 but the maximum gain is not) and the corresponding minimum and maximum installation loss (L_{min} and L_{max} in Figure 2-2). These limits should be defined in the installation instructions.

a) Equipment compatible with a minimum standard RTCA/DO-301-compliant antenna: The equipment shall *[LAAS-295]* accommodate GPS and SBAS signals with a minimum input signal power of -136.5 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 *[LAAS-296]* have the capability of tracking GPS, and if included, SBAS satellites with a minimum input signal power of -134 dBm in the presence of sky and antenna thermal noise density ($N_{sky,antenna}$) of -172.5 dBm/Hz and the Appendix D interference conditions. The equipment shall *[LAAS-297]* have the capability of tracking GPS satellites with a maximum power of at least -121 dBm. If SBAS satellites are included, the equipment shall *[LAAS-298]* have the capability of tracking SBAS satellites with a maximum power of at least -115.5 dBm.

b) Equipment compatible with a specific RTCA/DO-301-compliant antenna: All signal-in-space power levels in this paragraph are referenced to the output of a 0 dBi circularly polarized antenna. The equipment shall *[LAAS-299]* accommodate GPS and SBAS 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 *[LAAS-300]* have the capability of tracking GPS, and if included, SBAS satellites with a minimum signal-in-space 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 D interference conditions. The equipment shall *[LAAS-301]* have the capability of tracking GPS satellites with a maximum signal-in-space power of at least -123 dBm. If SBAS satellites are included, the equipment shall *[LAAS-302]* have the capability of tracking SBAS satellites with a maximum signal-in-space power of at least –119.5 dBm.

The manufacturer must specify any unique antenna requirements (e.g., minimum gain at 5 degree elevation angle, G/T ratio). The manufacturer must determine the minimum and maximum signal power levels at the antenna port, accounting for the antenna radiation pattern. The maximum signal power level may account for the combined satellite antenna and specific antenna radiation patterns. For the minimum standard antenna, this effect results in a 2 dB reduction in the maximum GPS signal power level with respect to the sum of the maximum signal in space and the maximum gain of the antenna radiation pattern. The GNSS noise and external interference are not adjusted by the antenna radiation pattern.

Note 1: *If a specific antenna is to be used, or the manufacturer elects to demonstrate tracking at a lower mask angle (< 5 degrees), then gain values must be adjusted, and sensitivity and dynamic range specified.*

Note 2: *$N_{sky,antenna}$ is determined by the antenna G/T for 1575.42 ±2MHz, as the correlation of the noise density outside ±2 MHz with the C/A code spectrum has a negligible effect. RTCA/DO-301 provides the method to determine sky and antenna thermal noise density ($N_{sky,antenna}$) from G/T. RTCA/DO-301 also provides for guidance on the preamplifier gain to support the test procedures.*

Note 3: *Acceptable acquisition and tracking performance may not be achievable for the minimum signal-in-space levels of -136.5 dBm depending on the external interference environment and actual level of inter- and intra-system interference. For SBAS signals, these effects can be managed by SBAS service providers for their service volumes, taking into account the actual power level, the user's antenna mask angle and resulting gain, and the actual level of inter- and intra-system interference. For GPS signals, the minimum signal-in-space power is -128.5 dBm.*

Note 4: *The requirements contained in this section are based on a minimum antenna gain of -5.5 dBic and a maximum antenna gain of +4.0 dBic.*

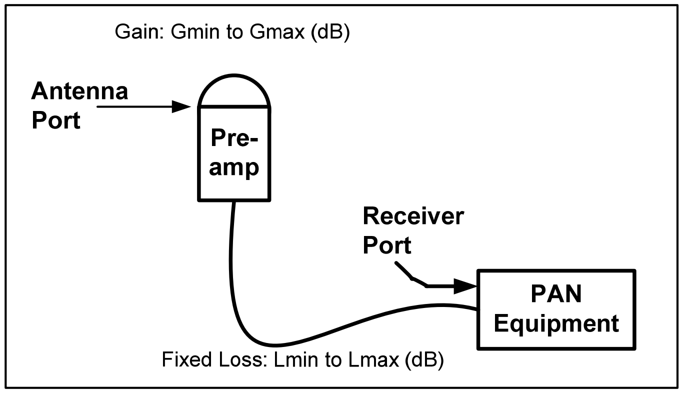


Figure 2-2 **Antenna with Preamplifier Configuration**

2.3.6.3 Equipment Burnout Protection

The PAN equipment shall *[LAAS-084]* withstand, without damage, an in-band Continuous Wave (CW) signal of +20 dBm at the output of the preamplifier.

Note: *For a DO-301 antenna, the output of the preamplifier (before any fixed loss shown in Figure 2-2) is limited to +20 dBm.*

2.3.6.4 GPS Signal Processing

The PAN equipment shall *[LAAS-085]* process the GPS signals and necessary data described in the GPS SPS Performance Standard, September 2008 and IS-GPS-200D with IRN-200D-001, "Navstar GPS Space Segment / Navigation User Interfaces", March 7, 2006. The GPS ionospheric corrections shall *[LAAS-086]* not be applied. GPS tropospheric corrections shall *[LAAS-087]* not be applied. However, the LAAS tropospheric corrections as specified in Section 2.3.8.3 must be applied.

The PAN equipment shall *[LAAS-088]* continue to decode ephemeris and clock parameters (subframes 1, 2, and 3 of the GPS navigation message) for all ranging sources being used in the navigation solution. The equipment shall *[LAAS-089]* retain multiple sets of GPS ephemeris and clock parameters to ensure that differential corrections can continue to be applied following an IOD change in the Type 1 message (Section 2.3.8.1.3).

The PAN equipment shall *[LAAS-090]* apply the satellite clock correction (including relativistic corrections) derived from the clock parameters in subframe 1 of the GPS navigation message (refer to the SPS Signal Specification) after smoothing the pseudorange measurement (Section 2.3.6.6).

Note 1: *GPS navigation data in subframes 1, 2, and 3 may not always be updated in the same frame.*

Note 2: *Equipment should be able to track satellites under conditions of ionospheric scintillation that could occur during solar maximum at auroral and equatorial latitudes. There is insufficient information to* *characterize scintillation and define appropriate requirements and tests for inclusion in this document. However, equipment should be able to track satellites through phase jitter and amplitude fading that can result from scintillation. New requirements may be defined when ionospheric effects can be adequately characterized.*

2.3.6.4.1 GPS Tracking Constraints

GPS satellites shall *[LAAS-303]* be tracked using either an early-minus-late or double delta delay lock loop discriminator.

For early-minus-late (E-L) delay lock loop (DLL) discriminator tracking of GPS satellites, the pre-correlation bandwidth of the installation, the correlator spacing (d), and the differential group delay shall *[LAAS-091]* be within the ranges as defined in Table 2-6 for the applicable AEC and illustrated in Figure 2-3.

Table 2-6 GPS Tracking Constraints for E-L DLL Discriminators

Region (see Figure 2-3)	3 dB Pre-correlation bandwidth, BW	Average Correlator Spacing (d) [C/A chips]	Instantaneous Correlator Spacing (d) [C/A chips]	Differential Group Delay	Applicable AEC
1	2<BW≤7 MHz	0.045-1.1	0.04-1.2	≤ 600 ns – D_A – D_C	C
2	7<BW≤16 MHz	0.045-0.21	0.04-0.235	≤ 150 ns – D_A – D_C	C & D
3	16<BW≤20 MHz	0.045-0.12	0.04-0.15	≤ 150 ns – D_A – D_C	C & D
4	20<BW≤24 MHz	0.08-0.12	0.07-0.13	≤ 150 ns – D_A – D_C	C & D

Note: D_A *is the differential group delay contribution of the antenna through the output of the pre-amp.* D_C *is the differential group delay contribution of the installation specific connection between the antenna and the PAN equipment.*

Note: *Region 4 is not practical for airborne equipment that also track SBAS ranging signals when implemented using a common receiver front end for receiving the GPS and SBAS signals. This is because the SBAS tracking constraints given in Table 2-9 do not include bandwidths in Region 4 of Table 2-6.*

The instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function. The average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame.

The discriminator (Δ) shall *[LAAS-092]* be based upon an average of early-minus late samples with spacings inside the specified range. Either a coherent or a non-coherent discriminator may be used.

For Double Delta (DD) DLL discriminators of the type $\Delta=2\Delta_{d1} - \Delta_{2d1}$ tracking GPS satellites, the pre-correlation bandwidth of the installation, correlator spacings (d_1 and $2d_1$) and the differential group delay shall *[LAAS-093]* be within the specified ranges as defined in Table 2-7 for the applicable AEC and illustrated in Figure 2-3. Either a coherent or a non-coherent discriminator may be used.

Table 2-7 GPS Tracking Constraints for DD DLL Discriminators

Region (see Figure 2-3)	3 dB Pre-correlation bandwidth, BW	Average Correlator Spacing (d_1 and $2d_1$) [C/A chips]	Instantaneous Correlator Spacing (d_1 and $2d_1$) [C/A chips]	Differential Group Delay	Applicable AEC
1	(-50*x)+12 <BW≤7 MHz	0.1-0.2	0.09-0.22	≤ 600 ns – D_A – D_C	C
	2<BW≤7 MHz	0.2-0.6	0.18-0.65		
2	(-50*x)+12<BW≤(133.33*x)+2.667	0.07-0.085	0.063-0.094	≤ 150 ns – D_A – D_C	C & D
	(-50*x)+12<BW<14MHz	0.085-0.1	0.077-0.11		
	7<BW≤14 MHz	0.1-0.24	0.09-0.26		
3	14<BW≤16 MHz	0.1-0.24	0.09-0.26	≤ 150 ns – D_A – D_C	C & D
	(133.33*x)+2.667<BW≤16MHz	0.085-0.1	0.077-0.11		

Note: D_A *is the differential group delay contribution of the antenna through the output of the pre-amp.* D_C *is the differential group delay contribution of the installation specific connection between the antenna and the PAN equipment.*

The differential group delay, which applies to the entire aircraft installed system, including that of the antenna (D_A), any installation specific cabling or active devices (D_C), and the RF front end of the PAN, must be bounded. However, there is some flexibility in the apportionment of differential group delay among these components.

If the equipment uses an RTCA/DO-301 minimum standard compliant antenna, D_A is 25 ns. If the equipment uses a specific RTCA/DO-301 compliant antenna, it may take advantage of any reduced differential group delay (i.e., D_A may be < 25 ns).

In addition, an aircraft installation consisting of only cable and connectors may be assumed to have a differential group delay contribution (D_C) of 0 ns. However, installations incorporating devices such as splitters or amplifiers may introduce additional differential group delay. The manufacturer may support such installations, but has no obligation to do so. In any event, the manufacturer must specify the maximum acceptable installation related differential group delay (D_C). This limit should be defined in the installation instructions.

Note: *Equipment built to earlier versions of the document are assumed to support only* $D_C = 0$*. The original receiver requirements derivation included no installation allocation.*

The differential group delay is defined as:

$$\frac{1}{360}\cdot\left|\frac{d[\Phi(f_1)]}{df}-\frac{d[\Phi(f_2)]}{df}\right|$$

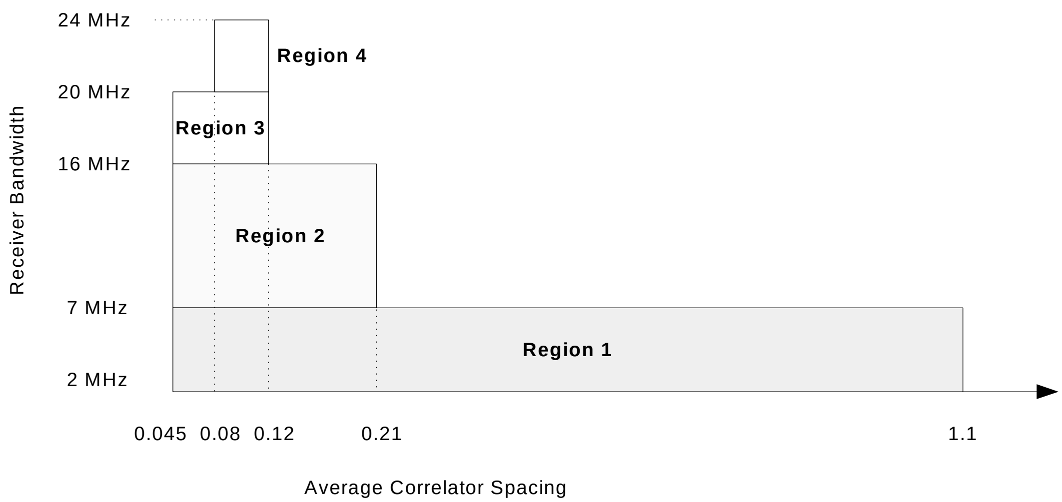
where:

f_1 and f_2 are any frequencies within the 3 dB bandwidth of the pre-correlation filter.

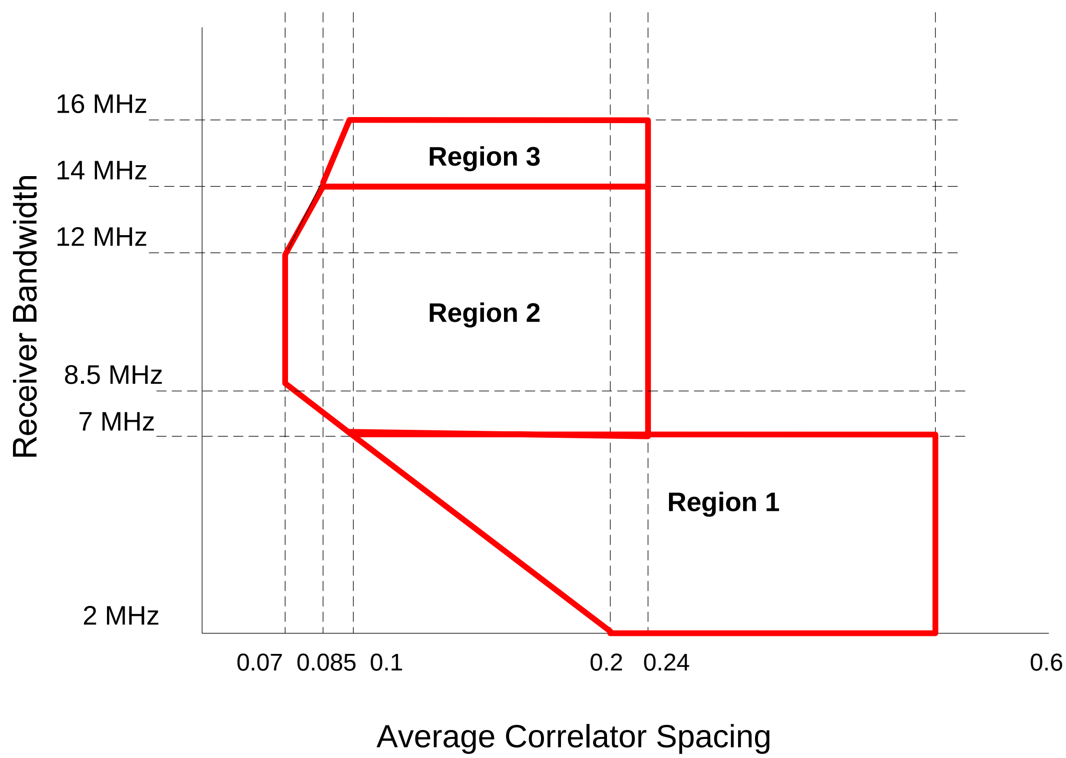
$\Phi(f)$ is the combined phase response of the equipment in degrees (excluding the antenna).

f is the frequency in Hz.

For the DD DLL discriminators, the pre-correlation filter shall *[LAAS-304]* roll-off by at least 30 dB per octave in the transition band which starts at the -3dB points, and the resulting attenuation in the stop band shall *[LAAS-396]* be greater than or equal to 50dB (relative to the peak gain in the pass band) at frequencies more than 24 MHz from the band center.



E-L Discriminator Tracking of GPS Satellites



DD Discriminator Tracking of GPS Satellites

<u>Figure 2-3</u> Receiver Bandwidth vs. Average Correlator Spacing

<u>Note</u>: The technical implementation of the airborne receiver must be constrained to enable the LAAS ground system to effectively protect the

airborne receiver from possible degradations in the GPS satellite signal. These constraints are described in terms of correlator spacing, receiver bandwidth and receiver differential group delay. The satellite signal degradations considered in developing these constraints included:

a) Distorted satellite signal causing multiple correlation peaks

b) Correlator peak distortion due to code coherent spurious signals (such as reflected signals or code transition induced wave forms in the satellite)

c) Code coherent spurious signals distorted by RF filter differences

d) Flat correlation peaks causing excessive noise or drift

e) Discriminator behavior based on transient distorted satellite signal conditions.

2.3.6.4.2 Correlation Peak Validation

The equipment shall *[LAAS-094]* acquire the main C/A code correlation peak for each GPS and SBAS ranging source used for the navigation solution.

For Double Delta DLL discriminators, the equipment shall *[LAAS-270]* operate at the correct tracking point corresponding to the strongest peak within the main C/A code correlation peak.

Note: *The requirement to track the strongest peak is based on the effect of potential satellite signal failures on DD DLL discriminators (see ICAO Annex 10 Attachment D, Section 8). It does not apply to E-L DLL discriminators. DD DLL discriminators may demonstrate compliance with this requirement by verifying that the strongest peak is tracked during acquisition and reacquisition. It is not necessary to continually monitor for this condition.*

2.3.6.4.3 GPS Satellite Acquisition Time

The equipment shall *[LAAS-095]* meet the satellite acquisition time requirements of DO-229().

2.3.6.4.4 GPS Satellite Reacquisition Time

The equipment shall *[LAAS-096]* meet the satellite reacquisition time requirements of DO-229().

2.3.6.4.5 GPS Satellite Initial Acquisition Time

The equipment shall *[LAAS-406]* meet the satellite initial acquisition time requirements specified in DO-229D with the exception that the interference environment specified for these requirements as DO-229D Appendix C be replaced with the interference environment specified in Appendix D of this MOPS.

2.3.6.5 SBAS Signal Processing

When providing deviations or PVT based on LAAS data, if using SBAS ranging sources, the equipment shall *[LAAS-097]* meet the requirements of RTCA/DO-229() identified in Table 2-8 with exceptions as noted.

Table 2-8 SBAS Ranging Source Requirements

DO-229D Section Reference	Subject
2.1.1.3.1	Acquisition and Track *Exception*: Do not apply ionospheric or SBAS tropospheric corrections. Tropospheric corrections for SBAS ranging sources must be applied as specified in section 2.3.8.2.1 of this MOPS. The interference environment specified as DO-229D Appendix C for these requirements must be replaced with the interference environment specified in Appendix D of this MOPS.
2.1.1.3.2	Demodulation and Forward Error Correction (FEC) Decoding *Exception*: The interference environment specified as DO-229D Appendix C for these requirements must be replaced with the interference environment specified in Appendix D of this MOPS.
2.1.1.3.3	SBAS Satellite Pseudorange Determination *Exception*: Do not apply any of the following corrections as specified in DO-229D: ionospheric, tropospheric, and SBAS differential corrections. Differential LAAS tropospheric corrections for SBAS ranging sources must be applied as specified in section 2.3.8.2.1 of this MOPS.
2.1.1.4	SBAS Message Processing *Exception*: Only SBAS Message Types 9 and 17 are utilized.
2.1.1.4.6	SBAS Message Type 9 - SBAS Satellite Navigation Message
2.1.1.4.7	SBAS Message Type 17 - SBAS Satellite Almanac
2.1.1.8.2	SBAS Satellite Acquisition *Exception*: The interference environment specified as DO-229D Appendix C for these requirements must be replaced with the interference environment specified in Appendix D of this MOPS.
2.1.1.9	Satellite Reacquisition Time *Exception*: The interference environment specified as DO-229D Appendix C for these requirements must be replaced with the interference environment specified in Appendix D of this MOPS.

SBAS satellites shall *[LAAS-305]* be tracked using either an early-minus-late or double delta delay lock loop discriminator.

Note: Receiver tracking implementations for SBAS satellites are restricted to the E-L and DD configurations defined below based on the rationale provided for tracking GPS satellites in Section 2.3.6.4.1.

For the E-L and DD DLL discriminator tracking of SBAS satellites, the pre-correlation bandwidth of the installation, correlator spacing, (d, d_1 and $2d_1$) and the differential group delay shall *[LAAS-288]* be within the range as defined inTable 2-9 for the applicable AEC.

Table 2-9 SBAS Ranging Function Tracking Constraints

Region	3 dB Pre-correlation bandwidth, BW	Average Correlator Spacing (d, d_1 and $2d_1$) [C/A chips]	Instantaneous Correlator Spacing (d, d_1 and $2d_1$) [C/A chips]	Differential Group Delay	Applicable AEC
1	$2<BW\leq 7$ MHz	0.045-1.1	0.04-1.2	$\leq$ 600 ns – $D_A - D_C$	C
2	$7<BW\leq 20$ MHz	0.045-1.1	0.04-1.2	$\leq$ 150 ns – $D_A - D_C$	C & D

Note: D_A is the differential group delay contribution of the antenna through the output of the pre-amp. D_C is the differential group delay contribution of the installation specific connection between the antenna and the PAN equipment.

For the DD DLL Discriminators, the pre-correlation filter shall *[LAAS-272]* roll-off by at least 30 dB per octave in the transition band.

2.3.6.6 Smoothing

These requirements apply to all equipment classifications.

The equipment shall *[LAAS-098]* perform carrier smoothing using the following filter:

$$P_{proj} = P_{n-1} + \frac{\lambda}{2\pi}\left(\phi_n - \phi_{n-1}\right)$$

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

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, 1^{st} 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), which is defined as follows:

After 100 seconds has elapsed since filter startup, α shall *[LAAS-306]* be equal to the sample interval in seconds divided by the time constant of 100 seconds.

In the first 100 seconds since filter startup, α shall *[LAAS-307]* be equal to the sample interval in seconds divided by either 100 seconds or the time in seconds since filter startup.

Notes:

1) *Smoothing can be done in parallel with other acquisition processes, making the smoothed pseudoranges available as quickly as possible.*

2) *This filter and the filter in the ground station are matched to avoid relative errors induced by ionospheric divergence.*

The raw pseudorange ρ_n shall *[LAAS-308]* be obtained using a code tracking loop that is carrier driven and of first order, or higher, and has a one-sided noise bandwidth $\geq$ 0.125 Hz.

2.3.6.6.1 GAST D Smoothing Requirement

LAAS equipment supporting GAST D, in addition to the set of smoothed pseudoranges defined in Section 2.3.6.6, shall *[LAAS-319]* produce a second set of smoothed pseudoranges by applying the filter defined in 2.3.6.6 where the filter weighting function (α) is defined as follows:

After 30 seconds has elapsed since filter startup, α shall *[LAAS-320]* be equal to the sample interval in seconds divided by the time constant of 30 seconds.

In the first 30 seconds since filter startup, α shall *[LAAS-321]* be equal to the sample interval in seconds divided by either 30 seconds or the time in seconds since filter startup.

Note: *Equipment supporting GAST D uses the Dual Smoothing Ionospheric Gradient Monitor described in Section 2.3.9.3 to detect certain errors due to smoothing filter lag and significant ionospheric delay gradients over the LAAS baseline of interest. The Dual Smoothing Ionospheric Gradient Monitor requires that the pseudoranges be smoothed with these two specific smoothing time constants and the filter as specified in 2.3.6.6.*

2.3.6.7 Measurement Quality Monitoring

The satellite signal tracking quality shall *[LAAS-100]* be monitored such that the allocated integrity risk due to undetected cycle slip or other undetected measurement faults is within the manufacturer's allocation.

Notes:

1) *The risk is allocated as part of the integrity budget and the continuity impact of these monitors is allocated within the continuity budget (reference section 2.3.2).*

2) *During an approach, satellite power levels may vary (e.g., due to elevation angles and fading effects that may result in cycle slips). If the satellite is used for positioning and guidance, the loss of the satellite may result in loss of function. The specified interference will further lower the signal-to-noise ratio. Excessive CW interference could cause large pseudorange errors – see Notes 3) and 4) below.*

3) *An example of a monitoring method to maintain integrity at low power and in the presence of normal interference is signal-to-noise ratio monitoring and navigation message parity checking.*

4) *A raw pseudorange measurement that deviates excessively from the projected smoothed pseudorange should be excluded from being used by the smoothing filter. If successive measurements are consistently discarded which would be the case if a carrier or pseudorange step has occurred, the carrier-smoothed pseudorange should not be used. One possible implementation:*

$$if\ |(\rho_n - P_{proj})| < 10\,m\ then$$

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

Otherwise

$$P_n = P_{proj}.$$

2.3.6.8 Accuracy

The accuracy requirements specified in Sections 2.3.6.8.1 and 2.3.6.8.1.1 represent the performance in steady state, including errors such as processing errors, thermal noise, and interference.

Notes:

1) *PAN accuracy performance is classified in terms of the Airborne Accuracy Designations.*

2) *Steady-state ionospheric divergence effects will also exist. The difference between the steady-state response of the smoothing filter implemented in the airborne equipment (as defined in Section 2.3.6.6) and the steady-state response of the ground filter (which meets the same requirements) will be due only to the permissible variations in the carrier-aided code tracking loop (filter order and noise bandwidth). This steady-state deviation will be accounted for in the broadcast σ_{pr_gnd}.*

2.3.6.8.1 GPS Satellites

The RMS of the total steady-state equipment contribution to the error in the 100-second smoothed corrected pseudorange for a GPS satellite ($RMS_{pr\_air,GPS}$) at the minimum and maximum signal levels (Section 2.3.6.2) shall *[LAAS-101]* be as follows.

Minimum signal level:

a) $RMS_{pr\_air,GPS} \leq 0.36$ meters for Airborne Accuracy Designator A, and

b) $RMS_{pr\_air,GPS} \leq 0.15$ meters for Airborne Accuracy Designator B.

Maximum signal level:

a) $RMS_{pr\_air,GPS} \leq 0.15$ meters for Airborne Accuracy Designator A, and

b) $RMS_{pr\_air,GPS} \leq 0.11$ meters for Airborne Accuracy Designator B.

Note: *The Airborne Accuracy Designator characterizes the airborne equipment's contribution to error in the differentially corrected pseudoranges. The Airborne Accuracy Designator consists of a single letter associated with the accuracy of the equipment. Two designators are defined in this document.*

2.3.6.8.1.1 Equipment Class Specific Accuracy Requirements

LAAS equipment with AEC C shall *[LAAS-322]* meet the requirements of either AAD A or AAD B.

LAAS equipment with AEC D shall *[LAAS-323]* meet the requirements of AAD B.

2.3.6.8.2 SBAS Satellites

The following requirements apply to LAAS equipment of all equipment classifications that use SBAS satellites.

The RMS of the total steady-state equipment contribution to the error in the 100-second smoothed corrected pseudorange for an SBAS satellite ($RMS_{pr\_air,SBAS}$) at the minimum and maximum signal levels (Section 2.3.6.2) shall *[LAAS-102]* be as follows:

Minimum signal level:

$RMS_{pr\_air,SBAS} \leq 1.8$ meters

Maximum signal level:

$RMS_{pr\_air,SBAS} \leq 1.0$ meters

Note: *This accuracy does not include the relative tracking bias addressed in the following requirement.*

The relative tracking bias of an SBAS satellite as compared to GPS satellites shall not *[LAAS-309]* exceed 5 m for a narrowband signal and 0.5 m for a wideband signal.

Note: *This bias is caused by differences in net group delay through the receiver correlator that result from the signal bandwidth of the SBAS satellite as compared to a GPS satellite. It is not observable in a satellite simulator* *that does not mimic the unique signal characteristics of the SBAS satellites. The characteristics of the narrowband and wideband SBAS signals for this requirement are defined in the test procedures (see Section 2.5.3.2.3). DO-229() Appendix T describes an acceptable tool to determine the relative tracking bias. Copies of the actual tool can be obtained through the RTCA Inc. online store at www.rtca.org and downloading the file: DO-229() GEO Bias Tool.*

2.3.6.9 Integrity in the Presence of Interference

The equipment shall *[LAAS-103]* not output misleading information in the presence of interference including interference levels above those specified in Appendix D.

Note: *This requirement is comprehensive in nature in that it is intended to prevent the output of misleading information under unintentional interference scenarios that could arise. It is not intended to address intentional interference. While it is impossible to completely verify through testing, an acceptable means of compliance can be found in Section 2.5.3.3.2.*

Note: *In order to support problem investigation and maintenance, it is recommended the equipment output the signal-to-noise ratio for each satellite. This data can be useful when determining if a particular outage is caused by the environment or by receiver anomalies.*

2.3.6.10 Integrity in the Presence of Abnormal Dynamics

Abnormal maneuvers are defined to be maneuvers having accelerations/jerks that exceed those specified for normal maneuvers in Table 2-5, up to the maximum values specified in Table 2-10.

Table 2-10 Abnormal Maneuvers

LAAS Equipment Outputs	Ground Speed	Horizontal Acceleration	Vertical Acceleration	Total Jerk
Precision Approach Guidance	250 kts	2.00 g	1.50 g	0.74g/s
PVT	800 kts	2.00 g	1.50 g	0.74g/s

During abnormal maneuvers, the equipment shall *[LAAS-104]* not output misleading information (i.e., the protection limits must bound the navigation errors).

When the aircraft returns to normal maneuvers from abnormal maneuvers, the equipment shall *[LAAS-105]* meet the accuracy requirements as specified in Section 2.3.6.8. During the abnormal maneuver period, alerts shall *[LAAS-106]* function as specified in Section 2.3.11.5.2.

2.3.6.11 Airborne Code Carrier Divergence Filtering

AEC D equipment shall *[LAAS-324]* operate the CCD filter defined in this section at all times.

The required airborne CCD monitor filter is defined by:

$$Z_j = (1-k)Z_{j-1} + k \cdot dz_j \qquad [1]$$

$$D_j = (1-k)D_{j-1} + k \cdot Z_j \qquad [2]$$

where:

Dj - is the filter output at epoch j

Zj - is a filter state at epoch j

k - is the filter weighting function, a unitless parameter equal to the sample interval in seconds divided by a time constant of 100 seconds

and

$$dz_j = \lfloor \rho_j - (\lambda / 2\pi)\phi_j \rfloor - \lfloor \rho_{j-1} - (\lambda / 2\pi)\phi_{j-1} \rfloor$$

ρ_i is the current code measurement in meters

ϕ_i is the current carrier phase in radians

λ is the carrier phase wavelength in meters.

After take off and until the approach and landing operation is completed, when the computed position is inside the PAR, any satellite associated with a CCD filter output greater than 0.0125 m/s within the last 20 minutes shall *[LAAS-325]* be removed from the precision approach position solution within 2 seconds unless fault detection according to Section 2.3.9.6.1 is used to validate the measurement.

Note: *The purpose of this monitor is to detect abnormally large gradients in the ionospheric delay that could cause unacceptable errors in the differential position solution. The long delay before reintroducing a satellite into the position solution is to ensure that the airplane does not track the motion of an iono-gradient and thereby experience a "stationary front" scenario.*

Note: *Exclusion of satellites by the CCD filter threshold test is limited to a time window from take-off until the landing operation is completed to avoid nuisance exclusions. The intent is to limit the inappropriate exclusion of satellites affected by multipath, due to low or no aircraft speed and the proximity to potential reflectors such as buildings. It is the airframe integrator responsibility to select appropriate mechanisms to avoid nuisance exclusions. One acceptable means is to preclude satellite exclusion is based upon factors such as weight-on-wheels, air-ground inputs discretes, and/ or aircraft speed.*

2.3.7 Message Processing Function

The PAN equipment for all equipment classifications shall *[LAAS-107]* be capable of processing LAAS Message Types 1, 2, and 4 as defined in the RTCA/DO-246().

The PAN equipment for equipment classification D shall *[LAAS-326]* be capable of processing LAAS Message Type 11.

When processing Type 2 messages, the PAN equipment shall *[LAAS-277]* utilize the message length parameter so that it can decode Type 2 messages without additional message blocks, as well as Type 2 messages with one or more additional message blocks.

Note: *This requirement assures compatibility with future as well as current Type 2 message structures. Future data broadcasts may contain multiple additional data blocks; e.g., to provide additional integrity parameters not yet defined in the ICD.*

2.3.7.1 VDB Message Validity Check

The PAN function shall *[LAAS-108]* perform the cyclic redundancy check (CRC) on all messages used and ignore any message for which the CRC, as defined in the RTCA/DO-246(), does not pass.

2.3.7.2 VDB Message Block Identifier Check

The PAN function shall *[LAAS-109]* check the Message Block Identifier (MBI) on all messages and ignore any message for which the MBI does not indicate a "Normal LAAS" message, as defined in the RTCA/DO-246().

2.3.7.3 VDB Message Authentication Protocols

The PAN equipment for airborne equipment classification D shall *[LAAS-327]* conform to the authentication protocols defined in this section.

Note: *It is recommended that all PAN equipment conform to the authentication protocols.*

The PAN equipment that conforms to Authentication Protocols shall *[LAAS-328]* check the first character of the Reference Path Identifier (RPI) after approach selection. If the character is in the set : { A, X, Z, J, C, V, P, T }, then the ground station supports Authentication Protocols, and the PAN equipment shall *[LAAS-329]* exercise protocols "a" through "f" below. When any of the VDB message authentication verification protocols fail, the equipment shall *[LAAS-330]* within 2 seconds remove or flag invalid the output of all deviations and differential PVT that are determined by applying LAAS differential corrections.

a) Verify that the Station Slot Identifier (SSID) from the VDB message training sequence matches the slot indicated by the coding of the first character in the RPI from the Type 4 Message FAS data block per Table 2-11.

b) Verify that Type 2 Messages from the selected ground station are received only in the slot indicated by the SSID.

Note: The selected ground station is indicated by the GBAS ID in the message header of the Type 4 Message that contains the FAS datablock with the RPDS that matches the RPDS derived from the channel number per section 2.3.5.

c) Verify that the Type 2 Message being used has been received within the last 1 minute.

d) Only use messages from slots assigned to the ground station in the Slot Group Definition (SGD) from the Type 2 Message, Additional Data Block 4.

e) Verify that the selected FAS Data Block does not change at any time after approach selection, otherwise discontinue use of the ground station. All bits of the FAS datablock must be checked. All bits of the FAS datablock must be checked each time the FAS datablock is received.

f) Verify that the Slot Group Definition does not change at any time after approach selection.

Note: The GPS receiver continues to output PVT in accordance with Section 2.1.

If the first character of the Reference Path Identifier (RPI) is not in the set of { A, X, Z, J, C, V, P, T }, then the ground station does not support Authentication Protocols, and the PAN shall *[LAAS-331]* not exercise the Authentication Protocols.

Table 2-11 RPI First Character Mapping to SSID

First Character of Reference Path Identifier	Corresponding SSID
A	0
X	1
Z	2
J	3
C	4
V	5
P	6
T	7

2.3.7.4 Message Processing Requirements for Forward Compatibility

The LAAS equipment shall *[LAAS-402]* not be adversely affected by the presence of any Message Type(s) in the VHF data broadcast signal that are not supported by the PAN function.

The LAAS equipment shall *[LAAS-403]* not be adversely affected by the presence of any additional data block(s) in a Message Type 2 in the VHF data broadcast signal that are not supported by the PAN function.

The LAAS equipment shall *[LAAS-404]* not be adversely affected by the presence of any FAS, TAP, or MA data block(s) in a Message Type 4 in the VHF data broadcast signal that are not supported by the PAN function.

Note: *The term "not be adversely affected" means that the LAAS equipment will continue to normally process information from the VDB and meet the relevant functional and performance requirements in this MOPS for the active Service Type. The standards for GBAS have been designed to be extensible in 3 different ways: through the addition of new message types, through the addition of additional data blocks in the Type 2 message, and through the addition of new approach definition data blocks in the Type 4 message. To ensure that LAAS airborne equipment continues to function properly when new capabilities are introduced, the airborne equipment must properly ignore unknown message types, additional data blocks in the Type 2 message, and unrecognized data blocks in the Type 4 message. Receiver designers must ensure that the presence of unrecognized content on the datalink will not prevent normal processing of data in recognized formats even if that data appears after the unrecognized content. For example, the receiver should be able to find and utilize a FAS datablock in a Type 4 message that occurs after a datablock describing another type of path definition in the Type 4.*

2.3.8 Corrected Pseudorange

2.3.8.1 Conditions for Use of Differential Corrections

2.3.8.1.1 Ephemeris CRC Conditions

A GPS ranging source shall *[LAAS-117]* not be used in the position solution until the ephemeris data received from that source is verified by calculating the ephemeris CRC as defined in the RTCA/DO-246() and comparing it to the Ephemeris CRC value broadcast in the Type 1 message. For each ranging source used in the position solution, the calculated CRC shall *[LAAS-273]* be compared to the broadcast CRC within 1 second after receiving a new broadcast IOD. A new broadcast IOD is one whose value is different from the broadcast IOD last received for the same ranging source. The equipment shall *[LAAS-118]* cease using any satellite for which the computed and broadcast CRC values fail to match.

Note: *The LGF will not immediately base its corrections on the satellite clock and ephemeris values in the GPS navigation message that has just changed, as described in RTCA/DO-246().*

2.3.8.1.2 Reference Time Conditions

All satellites used in the differential position solution shall *[LAAS-120]* use corrections from the same ground station and with the same reference time as indicated by the modified z-count, which is referred to as a set of differential corrections. For all equipment classes, this set contains differential corrections for the 100 second smoothed pseudoranges (from a Type 1 message or a linked pair of Type 1 messages). For AEC D LAAS Equipment when operating to provide GAST D, this set also contains differential corrections for the 30 second smoothed pseudoranges (from a Type 11 message or a linked pair of Type 11 messages) in addition to the 100-second differential corrections. The most recently received set of corrections shall *[LAAS-121]* be applied, including pseudorange corrections, range rate corrections, refractivity index, and scale height. If the number of measurements field in the Type 1 message indicates that there are no corrections, then the equipment shall *[LAAS-122]* not apply any corrections.

Note: *Differential corrections that do not belong to the same set cannot be used in the position solution since the clock errors in the pseudorange corrections may be relative to different sets of conditions.*

2.3.8.1.3 Other Ranging Source Conditions

The following conditions apply to all equipment classifications.

The differential corrections for a ranging source shall *[LAAS-123]* only be applied if all of the following conditions are met:

a) The σ_{pr_gnd} for that ranging source from the Type 1 message containing the 100-second differential correction for that ranging source is not set to "1111 1111" *[LAAS-136]*;

b) The measurement type is consistent with the airborne measurements being corrected *[LAAS-280]*;

c) For GPS satellites, the IOD associated with the differential correction matches the IODE associated with the ephemeris used to determine the satellite location and matches the eight least significant bits of the IODC *[LAAS-137]*;

d) The elapsed time from the receipt of the Type 1 message containing the 100-second differential correction for that ranging source is less than *[LAAS-138]* 7.5 seconds;

e) The difference between current time and the reference time of the corrections (derived from the modified z-count) is less than *[LAAS-139]* 10 seconds;

   Note: *More stringent time-out requirements are defined in the next section for AEC D equipment.*

f) The difference between the current time and the time of applicability (as derived from the modified z-count) for the ephemeris decorrelation parameter (P) from the Type 1 message low frequency data associated with that ranging source is less than *[LAAS-282]* 120 seconds.

Note: *Items e), and f) result in differential corrections from the ground subsystem not being applied for any ranging source. Refer to Section 2.3.1.*

2.3.8.1.3.1 Ranging Source Conditions for AEC D equipment

The following additional ranging source conditions apply for AEC D equipment when operating to provide GAST D.

The differential corrections for the 100-second and 30-second smoothed pseudoranges shall *[LAAS-332]* only be applied if all of the following conditions are met:

a) The $\sigma_{pr\_gnd\_30}$ for that ranging source from the Type 11 message containing the 30-second differential correction for that ranging source is not set to "1111 1111" *[LAAS-333]*;

b) The $\sigma_{pr\_gnd\_100}$ for that ranging source from the Type 11 message containing the 30-second differential correction for that ranging source is not set to "1111 1111" *[LAAS-334]*;

c) When the computed position is below 200 feet above the LTP/FTP, the elapsed time from the receipt of the Type 1 message containing the 100-second differential correction for that ranging source is less than *[LAAS-335]* 1.5 seconds;

d) When the computed position is below 200 feet above the LTP/FTP, the elapsed time from the receipt of the Type 11 message containing the 30-second differential correction for that ranging source is less than *[LAAS-336]* 1.5 seconds;

e) When the computed position is below 200 feet above the LTP/FTP, the difference between the current time and the reference time of the corrections (derived from the modified z-count) is less than *[LAAS-337]* 4 seconds;

f) When the computed position is 200 feet or more above the LTP/FTP, the elapsed time from the receipt of the Type 1 message containing the 100-second differential correction for that ranging source is less than *[LAAS-393]* 3.5 seconds;

g) When the computed position is 200 feet or more above the LTP/FTP, the elapsed time from the receipt of the Type 11 message containing the 30-second differential correction for that ranging source is less than *[LAAS-394]* 3.5 seconds;

h) When the computed position is 200 feet or more above the LTP/FTP, the difference between the current time and the reference time of the corrections (derived from the modified z-count) is less than *[LAAS-395]* 10 seconds;

i) The difference between the current time and the time of applicability (as derived from the modified z-count) for the ephemeris decorrelation parameter (P_D) from the Type 11 message low frequency data associated with that ranging source is less than *[LAAS-338]* 120 seconds.

2.3.8.2 Application of Differential Corrections

The corrected pseudorange is computed as follows and illustrated in Figure 2-4.

$P_{corrected} = P_n + PRC + RRC*(t - t_{zcount}) + TC + c*(\Delta t_{sv})_{L1}$

where:

$P_{corrected}$ is the corrected pseudorange (in meters) at the current time,

P_n is the smoothed pseudorange (in meters) at the current time (Section 2.3.6.6),

PRC is the pseudorange correction (in meters) from the appropriate message (sections 2.3.8.2.1 and 2.3.8.2.2),

RRC is the range rate correction (in meters/second) from the appropriate message (sections 2.3.8.2.1 and 2.3.8.2.2),

t is the current time (in seconds),

t_{zcount} is the time of applicability of the PRC (in seconds) from the appropriate message (sections 2.3.8.2.1 and 2.3.8.2.2),

TC is the tropospheric correction (Section 2.3.8.2.1),

c is the speed of light (in meters/second), and

$(\Delta t_{sv})_{L1}$ is the satellite clock correction, including relativistic corrections (Sections 2.3.6.4 and 2.3.6.5) (in seconds).

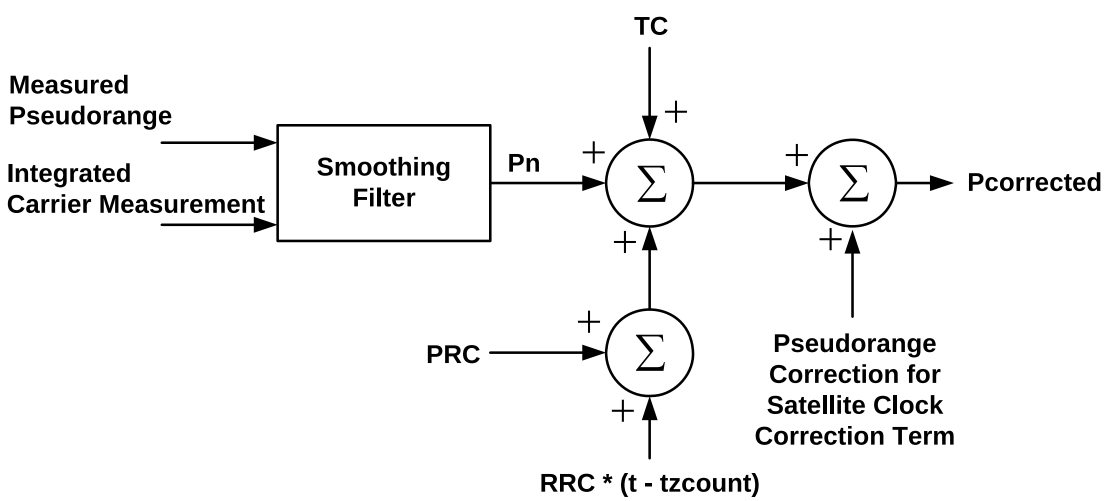


Figure 2-4 **Pseudorange Processing**

2.3.8.2.1 Application of Differential Corrections for 100 Second Smoothed Pseudoranges

LAAS Equipment for all AEC classifications and all Service Types shall *[LAAS-124]* apply the differential corrections for the 100 second smoothed pseudoranges as described in 2.3.8.2 where PRC and RRC are from the current Type 1 message.

2.3.8.2.2 Application of Differential Corrections for 30 Second Smoothed Pseudoranges

In addition to the requirement in Section 2.3.8.2.1, AEC D LAAS Equipment, when operating to provide GAST D, shall *[LAAS-339]* apply the differential corrections for the 30 second smoothed pseudoranges as described in 2.3.8.2 where PRC and RRC are from the current Type 11 message.

2.3.8.3 Tropospheric Correction

The airborne subsystem shall *[LAAS-125]* correct for the differential-troposphere delay error as follows:

$$TC = N_R\, h_0 \frac{10^{-6}}{\sqrt{0.002+\sin^2(\theta)}}\left(1-e^{-\Delta h / h_0}\right)$$

where:

N_R = refractivity index from the Type 2 message (unit less)

Δh= height of the aircraft above the GBAS reference point (meters)

θ = elevation angle of the satellite

h_0= tropospheric scale height from the Type 2 message (meters).

2.3.9 LAAS Differential Position Requirements

The PAN equipment shall *[LAAS-126]* compute three-dimensional position using a linearized, weighted least squares solution based on the differential corrections meeting the requirements of Section 2.3.8.1. The position solution shall *[LAAS-274]* use appropriate message types from the same ground station.

The PAN equipment shall *[LAAS-127]* not apply differential corrections unless differential corrections are available (Section 2.3.8.1) for four or more satellites for which corresponding airborne pseudorange measurements are available. When supporting GAST C or the positioning service, the PAN equipment shall *[LAAS-317]* use valid measurements from all satellites for which differential corrections are received, up to at least 10 satellites.

Note: *Valid measurements are those measurements that are from satellites that have been selected and pass all of the required monitor constraints (Section 2.3.6). Equipment supporting GAST D determines the geometry that is acceptable since subsets of the geometry may meet geometry screening requirements.*

The position solution shall *[LAAS-128]* reflect message data within one second of the output of the last bit of a valid message from the VDB function.

2.3.9.1 Differential Position Solution – One Acceptable Means

One acceptable means of computing the position based on the basic linearized GPS measurement model is given below.

<u>Note</u>: *The acceptable means illustrated is tailored to demonstrating the computations for the precision approach outputs using a position reference frame defined and illustrated in <u>Appendix C</u>.*

The measurement model is

$$\Delta y = G\,\Delta x + \varepsilon$$

where:

$\mathbf{\Delta x}$ is the four dimensional position/clock vector [ground-track (x-axis), cross-track (y-axis), up (z-axis) (in a standard right-handed coordinate system), and clock] relative to the position/clock vector $\mathbf{x}$ for which the linearization has been made (units of meters);

$\mathbf{\Delta y}$ is an N dimensional vector containing the Service Type dependent, differentially corrected pseudorange measurements defined in Section 2.3.8.2 (in meters) minus the expected ranging values based on the location of the satellites and the location of the user ($\boldsymbol{x}$);

N is the number of ranging measurements;

$\mathbf{G}$ is the observation matrix consisting of N rows of line of sight vectors from each satellite to $\boldsymbol{x}$, augmented by a "1" for the clock. Thus, the i^{th} row corresponds to the i^{th} satellite in view and can be written in terms of the azimuth angle Az_i *and* the elevation angle El_i. A positive azimuth angle is defined as counterclockwise about the z-axis from the positive x-axis, and a positive elevation angle is defined as upwards from the x-y plane. This matrix is unitless.

$$\mathbf{G_i} = \begin{bmatrix} -\cos El_i \cos Az_i & -\cos El_i \sin Az_i & -\sin El_i & 1 \end{bmatrix} = \text{i}^{\text{th}} \text{ row of } \mathbf{G}$$

$\boldsymbol{\varepsilon}$ is an N dimensional vector containing the errors in $\boldsymbol{y}$ (in meters).

The weighted least squares estimate of the states, $\Delta\hat{\boldsymbol{x}}$**,** can be found by:

$$\Delta\hat{\mathbf{x}} = \mathbf{S} \cdot \Delta\mathbf{y}$$

where:

$$\mathbf{S} \equiv \left(\mathbf{G}^{\mathrm{T}} \cdot \mathbf{W} \cdot \mathbf{G}\right)^{-1} \cdot \mathbf{G}^{\mathrm{T}} \cdot \mathbf{W}$$

$$\mathbf{W}^{-1} = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}$$

$\mathbf{W}^{-1}$ is the inverse of the least squares weighting matrix (units are meters squared)

σ_i is the fault-free error term (in meters) associated with satellite *i*.

$$\sigma_i^2 = \sigma_{pr\_gnd\_x}^2[i] + \sigma_{tropo}^2[i] + \sigma_{pr\_air}^2[i] + \sigma_{iono}^2[i]$$

Note: The computation of σ_i depends on the active Service Type. The source of the components $\sigma_{pr\_gnd\_x}$, and σ_{iono} may change depending on which Service Type is active. Service Type specific requirements related to the differential position solution are summarized in the following table.

Table 2-12 Summary of Service Type Specific Requirements for Weighting Computations

Service Type	$\sigma_{pr\_gnd\_x}[i]$	$\sigma_{iono}[i]$
Positioning Service, GAST C	*Message Type 1* $\sigma_{pr\_gnd}[i]$	*Computed per Section 2.3.12.3 using $\sigma_{vert\_iono\_gradient}$ from Message Type 2, and a time constant τ of 100 seconds*
GAST D	*Message Type 11* $\sigma_{pr\_gnd\_30}[i]$	*Computed per Section 2.3.12.3 using $\sigma_{vert\_iono\_gradient\_D}$ from Message Type 2 Additional Data Block 3, and a time constant τ of 30 seconds*

$\sigma_{pr\_gnd\_x}[i]$ is the Approach Service Type dependent total (post correction) fault-free error term (in meters) associated with the corresponding differential correction for satellite *i*, as defined in RTCA/DO-246().

$\sigma_{tropo}[i]$ is the residual tropospheric uncertainty (in meters) for satellite *i,* as defined in Section 2.3.12.2.

$\sigma_{pr\_air}[i]$ is the total (post correction) fault-free airborne error term (in meters) for satellite *i,* see Section 2.3.12.1.

$\sigma_{iono}[i]$ is the Service Type dependent residual ionospheric uncertainty (in meters) for satellite i, computed per Section 2.3.12.3.

S is the projection matrix (unitless) that relates the range domain measurements ($\Delta\mathbf{y}$) to the position domain estimates ($\Delta\hat{\mathbf{x}}$).

The magnitude of the three-dimensional position error induced by discontinuities between sets of differential corrections relative to the weighted least squares position solution defined above shall *[LAAS-129]* be less than 1 cm, where the discontinuity is limited by the range of the differential corrections.

<u>Note</u>: *These discontinuities arise from the fact that each set of differential corrections may contain an error common to all corrections in the set, but the error may not be continuous between message updates.*

2.3.9.2 Service Type Specific Differential Position Solution Requirements

Section 2.3.9.1 defines the general form of the differential position solution. Exactly which information from the ground station is used in the differential position solution depends on the type of service (i.e., positioning service vs. approach service) and the active Approach Service Type. The following section defines the specific requirements for each Service Type.

<u>Note</u>: *The active approach service type is determined by the selected approach, the current satellite geometry, and the current functional status of the ground and airborne equipment.*

2.3.9.2.1 Differential Position Solution for the GBAS Positioning Service

The following requirements apply at all times for all AEC:

a) The position solution used to provide PVT outputs shall *[LAAS-340]* be based on 100 second smoothed pseudoranges corrected with corrections obtained from Message Type 1.

b) The projection matrix (S), as defined in section 2.3.9.1, used to compute the position solution for PVT outputs shall *[LAAS-341]* be computed based on σ_i computed using $\sigma_{pr\_gnd}[i]$ from Message Type 1 and $\sigma_{iono}[i]$ per section 2.3.12.3 using $\sigma_{vert\_iono\_gradient}$ from Message Type 2 and a time constant τ of 100 seconds.

2.3.9.2.2 Differential Position Solution for Approach Service GAST C

When the active Approach Service Type is C, the following requirements apply:

a) The position solution used to generate deviations shall *[LAAS-342]* be based on 100 second smoothed pseudoranges corrected with corrections obtained from Message Type 1.

b) The projection matrix (S), as defined in section 2.3.9.1, used to compute the position solution shall *[LAAS-343]* be computed based on σ_i computed using $\sigma_{pr\_gnd}[i]$ from Message Type 1, and $\sigma_{iono}[i]$ computed per section 2.3.12.3 using $\sigma_{vert\_iono\_gradient}$ from Message Type 2 and a time constant τ of 100 seconds.

2.3.9.2.3 Differential Position Solution for Approach Service GAST D

When GAST D is active, the PAN will compute two different position solutions: one based on 30 second smoothed pseudoranges and the other based on 100 second smoothed pseudoranges. The following requirements apply:

a) A position solution shall *[LAAS-344]* be computed based on 100 second smoothed pseudoranges corrected with corrections obtained from Message Type 1.

b) A second position solution used to determine deviations shall *[LAAS-345]* be computed based on 30 second smoothed pseudoranges corrected with corrections obtained from Message Type 11.

c) The projection matrix (S) as defined in section 2.3.9.1 shall *[LAAS-346]* be used for both position solutions. This S is computed based on σ_i computed using $\sigma_{pr\_gnd\_30}[i]$ from Message Type 11, and $\sigma_{iono}[i]$ computed per section 2.3.12.3 using $\sigma_{vert\_iono\_gradient\_D}$ from Message Type 2 Additional Data Block 3 and a time constant τ of 30 seconds.

2.3.9.3 Dual Solution Ionospheric Gradient Monitoring

AEC D equipment, when supporting GAST D, shall *[LAAS-347]* compute the difference between the 30 second smoothed and 100 second smoothed position solutions. If the absolute value of the difference between the position solutions in the vertical or lateral direction exceeds 2 meters, the equipment shall *[LAAS-348]* change the active Approach Service Type to C and output appropriately per section 2.3.11.1.3.3, or use a subset geometry for which this test passes.

2.3.9.4 Satellite Geometry Screening

For AEC D equipment, when GAST D is active, the PAN shall *[LAAS-349]* perform the following geometry screening:

a) Compute the vertical alert limit (VAL) as the minimum of VAL (defined in Section 2.3.11.5.2.1.3) and a user-specified maxVAL.

b) Compute the lateral alert limit (LAL) as the minimum of LAL (defined in Section 2.3.11.5.2.1.3) and a user-specified maxLAL.

<u>Note</u>: *The user-specified maxVAL and maxLAL might not be fixed values. For example, they may be a function of height and horizontal distance, respectively.*

c) When the aircraft is inside the PAR, compare the maximum absolute value of any single $S_{Apr\_vert,i}$ (defined in Section 2.3.11.5.2.1.4) to a user-specified limit, maxSvert. If the limit is exceeded, change the active Approach Service Type to C and output appropriately per section 2.3.11.1.3.3, or use a subset geometry for which the limit is not exceeded.

d) When the aircraft is inside the PAR, compare the maximum absolute value of any single $S_{Apr\_lat,i}$ (defined in Section 2.3.11.5.2.1.4) to a user-specified limit, maxSlat. If the limit is exceeded, change the active Approach Service Type to C and output appropriately per section

2.3.11.1.3.3, or use a subset geometry for which the limit is not exceeded.

e) When the aircraft is inside the PAR, compare the sum of the two maximum absolute values of $S_{Apr\_vert,i}$ (defined in Section 2.3.11.5.2.1.4) to a user-specified limit, maxSvert2. If the limit is exceeded, change the active Approach Service Type to C and output appropriately per section 2.3.11.1.3.3, or use a subset geometry for which the limit is not exceeded.

Note: *These user-specified limits are dependent on the design of the total aircraft integration and its ability to meet airworthiness certification criteria for Category III precision approach procedures. Geometry screening limits selected to help an airplane design meet airworthiness requirements will have an impact on continuity and availability unique to the design and will require consideration. Appendix J briefly describes the current Category III airworthiness criteria, and it gives some examples of how to determine these limits in order to meet the criteria. The FAA is currently assessing the adequacy of its current criteria and advisory material for GBAS-supported Category III precision approach procedures. Additional material is expected to be developed.*

2.3.9.5 Differential Correction Magnitude Check

The PAN equipment for airborne equipment classification D shall *[LAAS-350]* perform the Differential Correction Magnitude Check in this section.

Note: *It is recommended that all PAN equipment perform the Differential Correction Magnitude Check.*

The PAN equipment that performs the Differential Correction Magnitude Check shall *[LAAS-351]* compute the magnitude of the projection of the total differential corrections to each measured pseudorange into the horizontal position for the position solution being used. If the magnitude is larger than 200 meters, then the equipment shall *[LAAS-352]* within 2 seconds remove or flag invalid the output of all deviations and differential PVT that are determined by applying LAAS differential corrections.

For example, if the differential position solution is computed according to Section 2.3.9.1, then the Horizontal Position Differential Correction Magnitude (HPDCM) would be computed as follows:

$$HPDCM = \sqrt{x_1^2 + x_2^2}$$

where:

$$\overline{x} = \mathbf{S} \cdot \overline{\delta PR}$$

$\overline{\delta PR}$ is a vector of pseudorange corrections. δPR_i is defined as the total correction to the measured pseudorange for satellite i, and is computed as follows:

$$\delta PR_i \equiv PRC_i + RRC_i*(t - t_{zcount}) + TC_i + c*(\Delta t_{sv,i})_{L1}$$

S is the weighted least squares projection matrix S (reference Section 2.3.9.1) used in the differential position solution, and $\bar{x}$ is the projection of $\overline{\delta PR}$ into position and time, where x_1 and x_2 are the horizontal position components of $\bar{x}$.

2.3.9.6 Fault Detection

For AEC D equipment, when GAST D is active and the aircraft is inside the PAR the PAN shall *[LAAS-353]* perform fault detection on the precision approach position solution based on 30-second smoothing using redundant corrected pseudorange measurements if more than four satellites with associated differential corrections are available.

The fault detection algorithm shall *[LAAS-354]* be performed at a rate of at least once per minute, as well as within 6 seconds of entering the PAR and within 2 seconds of a satellite geometry change. If a fault is detected, the equipment shall *[LAAS-355]* change the active Approach Service Type to C and output appropriately per section 2.3.11.1.3.3, or use a subset geometry for which the limit is not exceeded.

The probability of missed detection has no requirement. The threshold shall *[LAAS-356]* be set to provide a probability of false alert equal to 10^{-7} per sample.

<u>Note</u>: *This fault detection algorithm is intended to provide additional means for detection of rare ionosphere gradient anomalies and position errors that may go undetected by other methods required by this MOPS.*

2.3.9.6.1 Fault Detection for Satellite Addition

Equipment supporting GAST D shall *[LAAS-357]* perform fault detection as specified in this section at least once after the airborne Code Carrier Divergence monitor output has converged below its threshold (see Section 2.3.6.11).

The equipment shall *[LAAS-358]* form a test statistic and compare it to a threshold set to provide a Probability of False Alert of no greater than 0.01/minute. In addition, a vertical protection level, VPL_{FD}, and a lateral protection level, LPL_{FD}, shall *[LAAS-397]* be computed based on the detection thresholds and a probability of missed detection of 10^{-3}/minute. LPL_{FD} and VPL_{FD} shall *[LAAS-398]* be computed based on the hypothesis that there is a bias (due to a stationary ionosphere gradient) affecting only the satellite measurement to be added (as opposed to the hardest to detect satellite measurement), and with all other measurement errors defined by their expected distributions.

The satellite measurement shall *[LAAS-359]* not be added to the precision approach position solution until the 20-minute observation period required by the airborne Code Carrier Divergence monitor has elapsed (See Section 2.3.6.11), or until the VPL_{FD} is less than VAL (as defined in Section 2.3.9.4), LPL_{FD} is less than LAL (as defined in Section 2.3.9.4), and the test statistic is below the threshold.

<u>Note</u>: *This RAIM algorithm may be performed multiple times at any frequency until the conditions are met for satellite addition as long as it meets the specified missed detection probability.*

2.3.10 Position, Velocity, and Time (PVT) Outputs

When outputting the PVT based on GBAS differential corrections, the requirements in this section and its subsections apply.

Note: *The GBAS positioning service is a service that is distinct and separate from the GBAS precision approach services categorized by GBAS Approach Service Types. For the positioning service the PAN always computes a position solution based on the 100 second smoothed pseudoranges and differential corrections supplied in the current Type 1 message.*

The PAN equipment shall *[LAAS-278]* verify the following before commencing the output of differentially corrected position:

a) The ground station supports the differentially corrected positioning service (i.e., verify that RSDS is provided, and that it is not equal to '1111 1111').

b) The distance (slant range) between the aircraft and the GBAS reference point is less than the maximum GBAS usable distance (D_{max}), if D_{max} is provided in the Type 2 message being used.

The PAN equipment shall *[LAAS-130]* output differentially-corrected position based on the 100-second smoothed pseudoranges and pseudorange corrections, in latitude, longitude and height above the WGS-84 ellipsoid, three-dimensional velocity (east, north, and up), and time at a rate of at least once per second.

Note: *A position output at 5 Hz or more may be required to support other applications.*

Note: *The time output may be a mark that indicates the time of applicability of the position and velocity. Some applications may require the output of the time in UTC.*

2.3.10.1 Message Processing -- GBAS ID Selection

The PAN function will only use messages for which the GBAS Identification (ID) in the message block header matches the GBAS ID in the Type 2 message being used to determine the differential PVT outputs. (Reference Section 2.3.9, LAAS-274.)

2.3.10.2 Protection Level, Ephemeris Error Bound, & Figures of Merit

While providing differentially corrected position outputs, the LAAS equipment shall *[LAAS-180]* compute the Horizontal Protection Level (HPL_{POS}) and Horizontal and Vertical Position Figures of Merit ($HFOM_P$ & $VFOM_P$) of the LAAS signal-in-space, for each PVT output.

While providing differentially corrected position outputs, the equipment shall *[LAAS-131]* output a horizontal protection level for each PVT output. The equipment shall *[LAAS-132]* indicate if the protection level cannot be calculated.

$$HPL_{POS} = \max\{HPL_{H0}, HPL_{H1}, HPB_e\}$$

Note: HPL_{POS} supports a SIS integrity of greater than or equal $1\text{-}10^{-7}$ per hour.

The vertical and horizontal position figures of merit ($VFOM_P$ and $HFOM_P$ respectively) and horizontal protection level under the H_0 hypothesis (HPL_{H0}) are:

$$VFOM_P = 2\sqrt{\sum_{i=1}^{N} s_{vert,i}^2 \sigma_i^2}$$

$$HFOM_P = 2d_{major}$$

$$HPL_{H0} = 10d_{major}$$

where:

$s_{(),()}$ ≡ elements of the weighted least squares projection matrix **S** (reference Section 2.3.9) used in the generation of the position for the PVT output

$s_{vert,i}$ = projection of the local vertical component for the i[th] ranging source

$s^2_{hrz,i} = s^2_{1,i} + s^2_{2,i}$ = projection of the local horizontal component for i[th] ranging source squared.

$$d_{major} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$

$d_x^2 = \sum_{i=1}^{N} s_{1,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the "1" axis

$d_y^2 = \sum_{i=1}^{N} s_{2,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the "2" axis

$d_{xy} = \sum_{i=1}^{N} s_{1,i} s_{2,i} \sigma_i^2$ = covariance of the model distribution in the "1" and "2" axes

σ_i ≡ weightings used in the least squares solution (reference Section 2.3.9)

The protection levels under the H_1 hypothesis are:

$$HPL_{H1} = \max\left[HPL_{H1}[j]\right]$$

where:

$HPL_{H1}[j]$ for all j (1 to MAX { M[i] }) as follows:

$$HPL_{H1}[j] = \left|B_{j\_H}\right| + K_{md\_POS\_hrz} d_{major\_H1}$$

$$B_{j\_H} = \sqrt{\left(\sum_{i=1}^{N} s_{1,i} B[i,j]\right)^2 + \left(\sum_{i=1}^{N} s_{2,i} B[i,j]\right)^2}$$

$$d_{major\_H1} = \sqrt{\frac{d\_H1_x^2 + d\_H1_y^2}{2} + \sqrt{\left(\frac{d\_H1_x^2 - d\_H1_y^2}{2}\right)^2 + d\_H1_{xy}^2}}$$

$d\_H1_x^2 = \sum_{i=1}^{N} s_{1,i}^2 \sigma_{i\_H1}^2$ = variance of model distribution that overbounds the true error distribution in the "1" axis

$d\_H1_y^2 = \sum_{i=1}^{N} s_{2,i}^2 \sigma_{i\_H1}^2$ = variance of model distribution that overbounds the true error distribution in the "2" axis

$d\_H1_{xy} = \sum_{i=1}^{N} s_{1,i} s_{2,i} \sigma_{i\_H1}^2$ = covariance of the model distribution in the "1" and "2" axes

$\sigma^2_{i\_H1}$ ≡ reference Section 2.3.11.5.2.1.4

$K_{md\_POS\_hrz}$ ≡ 5.3 (unitless)

M[i] = number of ground subsystem reference receivers whose pseudorange measurement was used to determine the differential correction for the i^{th} ranging source used in the position solution

B[i,j] = the B value (in meters) for the i^{th} ranging source and j^{th} reference receiver as indicated in the Type 1 Message

Note: *The PAN applies the value of zero for each of B value set to the bit pattern "1000 0000." This bit pattern indicates that the measurement is not available.*

The ephemeris error position bound is given by:

$$HPB_e = \max(HPB_e[k])$$

where:

P_k = ephemeris decorrelation parameter for ranging source k broadcast in the Type 1 message

x_{air} = distance (slant range) between the aircraft and the GBAS reference point (in meters)

$HPB_e[k]$ is the horizontal ephemeris error position bound for the k^{th} GPS ranging source used in the position solution, where $HPB_e[k]$ is computed for all GPS ranging sources used in the position solution:

$$HPB_e[k] = \left| s_{hrz,k} \right| x_{air} P_k + K_{md\_e\_POS\_hrz} d_{major}$$

$K_{md\_e\_POS\_hrz} = K_{md\_e\_POS}$ = the broadcast multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite (unitless)

Notes:

1) *The ephemeris error position bound is computed only for GPS satellites used in the position solution (k index) and not for other types of ranging sources (e.g., SBAS satellites) that are not subject to undetected ephemeris failures. However, the calculation of this position bound uses information from all ranging sources used in the position solution (i index).*

2) *Optionally, $s_{Apr\_vert,i}$ can be substituted for $s_{vert,i}$ when calculating the vertical figure of merit (VFOM) for the position when an approach is selected since it is more conservative.*

2.3.10.3 Figures of Merit Outputs

While providing differentially corrected position, the equipment shall *[LAAS-133]* output horizontal and vertical position figures of merit ($HFOM_P$ and $VFOM_P$) at least once per second as defined in Section 2.3.10.2. The equipment shall *[LAAS-134]* indicate if the $HFOM_P$ or $VFOM_P$ cannot be calculated.

If the equipment provides velocity figure of merit outputs, the equipment shall *[LAAS-360]* output a horizontal velocity figure of merit ($HFOM_V$) and vertical velocity figure of merit ($VFOM_V$) at least one per second.

Note 1: *An example of a means of computing the velocity and velocity figures of merit is given in DO-229D, Appendix F.*

Note 2: *Since ADS-B equipment will treat a velocity input with an $HFOM_V$ value of exactly 10 m/s (or greater) or a $VFOM_V$ value of exactly 50 ft/s (or greater) as having no velocity accuracy, and thus the particular implementation of the quantization of the Velocity Figure of Merit output may cause ADS-B equipment to ignore the velocity output unnecessarily (i.e., horizontal velocity accuracy is actually < 10 m/s, but is reported as exactly 10m/s and similarly for the vertical velocity), it is important that* *the resolution of the $HFOM_V$ and $VFOM_V$ outputs be sufficiently precise to preclude unnecessarily penalizing velocity output utilization.*

2.3.10.4 PVT Output Latency

The latency of the differentially corrected position, velocity, and time outputs, and their associated protection level and FOM outputs, defined as the interval between the time of the measurement and the time of applicability of the position, shall *[LAAS-151]* be less than or equal to 500 milliseconds.

The data defining the differentially corrected position shall *[LAAS-135]* be output prior to 200 milliseconds after the time of applicability.

2.3.10.5 Velocity Accuracy

The LAAS equipment horizontal velocity output shall *[LAAS-361]* have an error that is less than 10 m/s, (95th percentile), when the HDOP is normalized to 1.5 and the vertical velocity output shall *[LAAS-362]* have an error that is less than 50 ft/s, (95th percentile), when the VDOP is normalized to 3.0. These requirements shall *[LAAS-363]* be met under the minimum signal conditions defined in Section 2.3.6.2.

Note 1: *The velocity accuracy requirements [LAAS-361 and LAAS-362] are design requirements. These requirements do not imply that if the velocity FOMs at the time of applicability are equal to or greater than 10 m/s and 50 ft/s for the horizontal and vertical velocities respectively that the velocity should stop being output or flagged invalid. Rather, the velocities should continue to be output and the velocity FOMs (if provided as outputs) should continue to appropriately characterize the velocity accuracy.*

Note 2: *The test requirement in Section 2.5.3.4 defines an acceptable means of determining the 95th percentile velocity accuracy.*

2.3.11 Precision Approach Guidance Outputs

2.3.11.1 Message Processing

Note: *Message processing depends on the type of equipment. Equipment compliant with DO-253B and earlier versions of this MOPS supports only one type of approach service. Equipment built to this MOPS may be capable of supporting multiple types of approach service. Consequently, in the following sections message processing is defined for single Approach Service Type capable equipment as well as multiple Approach Service Type capable equipment. Single Approach Service Type capable equipment is by definition AEC-C and functional requirements for GAST C are used at all times. Multiple Approach Service Type capable equipment will have two states that are pertinent: the selected Approach Service Type and the active Approach Service Type. The selected Approach Service Type is the Approach Service Type indicated by the channel selection/Approach Service Type selection of the approach. The* *active Approach Service Type is the type of service that corresponds to the functional requirements currently supported by the equipment.*

2.3.11.1.1 FAS Data Block Selection and Confirmation

The PAN function shall *[LAAS-110]* select from the Type 4 message(s) the Final Approach Segment (FAS) data set corresponding to the selected approach (Section 2.3.5). The PAN shall *[LAAS-111]* validate the CRC for the selected FAS data block and only use it if the FAS data block CRC, as defined in the RTCA/DO-246(), passes. The PAN function shall *[LAAS-112]* output the corresponding Reference Path Identifier for the validated FAS data block.

2.3.11.1.2 GBAS ID Selection

For determining Precision Approach Guidance Outputs, when a FAS data block has been selected, the PAN function shall *[LAAS-113]* only use messages for which the GBAS Identification (ID) matches the GBAS ID in the Type 4 message containing the selected FAS data block.

2.3.11.1.3 Approach Service Type (AST) Selection

2.3.11.1.3.1 AST Selection for Single Approach Service Type Capable Equipment

LAAS equipment that supports a single Approach Service Type applies functional requirements for GAST C. In this case no selection is required; the selected Approach Service Type and the active Approach Service Type are both considered to be GAST C.

2.3.11.1.3.2 AST Selection for Multiple Approach Service Type Capable Airborne Equipment

The selected Approach Service Type for LAAS Equipment that supports multiple types of approach service shall *[LAAS-364]* not be reflected until the RPDS derived from the channel number (Section 2.3.5) or input to the PAN is found in a FAS data block in any received Type 4 message.

LAAS Equipment that supports multiple types of approach services shall *[LAAS-365]* do the following each time the GCID is verified per Section 2.3.11.4:

a) Check the status of GCID in the Type 2 message to determine if the ground system supports multiple types of approach service.

b) If GCID is coded as "1", then the selected Approach Service Type shall *[LAAS-399]* be set to "C" and functional requirements for GAST C shall *[LAAS-400]* be applied.

c) If GCID is coded as "2", "3", or "4" then the equipment shall *[LAAS-401]* set the selected service type to the highest GAST supported by both the equipment and the type of service indicated in the Approach Performance Designator (APD) specified in the selected Final Approach Segment data block from the Type 4 message.

2.3.11.1.3.3 Approach Service Type Output

LAAS Equipment that supports multiple types of approach services shall *[LAAS-366]* output the selected Approach Service Type as well as the active Approach Service Type. When the conditions are satisfied for a change in the Approach Service Type, the output shall *[LAAS-367]* reflect the change within 2 seconds.

2.3.11.2 Precision Approach Region

The Precision Approach Region (PAR) associated with an approach procedure is the region defined by the following conditions (see Figure 2-5):

a) Distance to the Landing Threshold Point (LTP)/Fictitious Threshold Point (FTP) in the horizontal plane < 10 nmi;

b) Bearing to the indicated end of the runway is within ± 90 degrees of the FAS bearing;

c) Proportional lateral deviation is within twice full scale; and

d) Aircraft position is below twice the full-scale fly down on the proportional vertical deviations or below a height of 200 feet above the LTP/FTP.

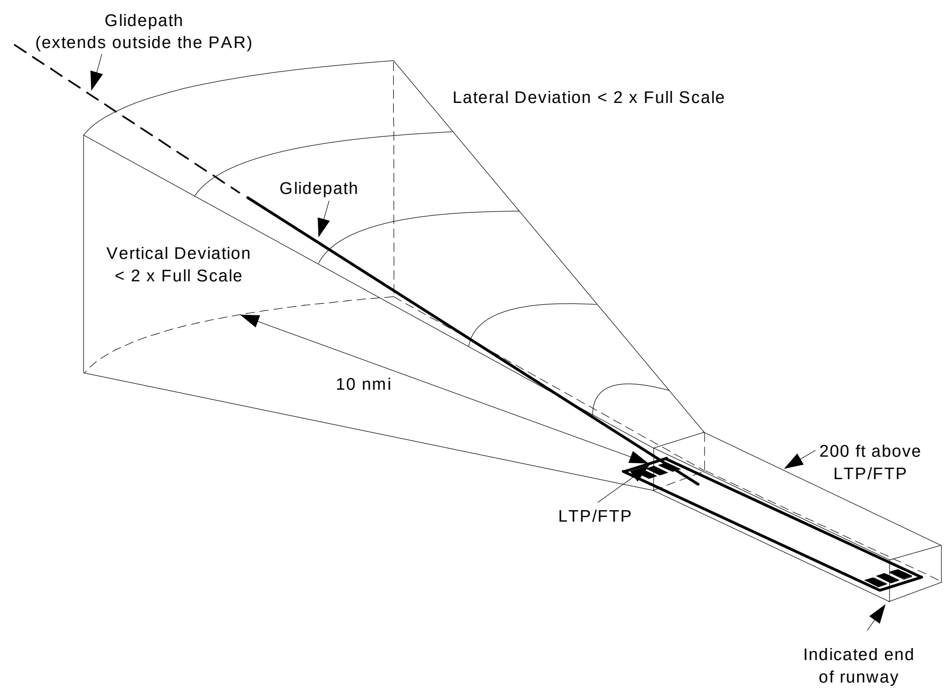


Figure 2-5 **Precision Approach Region**

Notes:

1) *The indicated end of the runway, or stop end of the runway, is defined by the parameters in the FAS data block associated with the selected approach by the parameters Δlength offset and the FPAP location.*

2) *The twice full-scale proportional lateral deviations between the LTP/FTP and the indicated end of the runway may be rectilinear or angular.*

2.3.11.3 Approach Status Verification

The equipment shall *[LAAS-283]* evaluate the FAS vertical and lateral alert limit/approach status fields:

a) for each selected FAS data block received when the aircraft is outside the PAR; or

b) once before outputting valid deviation if the approach is selected while the aircraft is inside the PAR.

After the aircraft is inside the PAR, and once the FAS vertical and lateral alert limit/approach status fields have been verified at least once, the equipment shall *[LAAS-284]* stop checking the FAS vertical and lateral alert limit/approach status fields.

When the vertical and lateral alert limit/approach status fields are evaluated, the PAN equipment shall *[LAAS-285]*, within 1 second:

a) indicate the vertical deviations are invalid if the FAS vertical alert limit/approach status field is coded as "1111 1111" in the most recently received FAS block associated with the selected approach.

b) indicate the vertical and lateral deviations are invalid if the FAS lateral alert limit/approach status field is coded as "1111 1111" in the most recently received FAS block associated with the selected approach.

2.3.11.4 Ground Continuity Integrity Designator (GCID) Conditions

The PAN equipment shall *[LAAS-114]* not output valid deviations until it verifies that the Ground Continuity Integrity Designator (GCID) in the Type 2 message is 1, 2, 3 or 4, as defined in the RTCA/DO-246(). When outside the PAR, the equipment shall *[LAAS-115]* continually verify the GCID and invalidate the deviation outputs within 1 second of receiving a Type 2 message with GCID set to other than 1, 2, 3 or 4. When inside the PAR, the equipment shall *[LAAS-116]* disregard any changes in the GCID.

2.3.11.5 Outputs

2.3.11.5.1 Deviations

The PAN equipment shall *[LAAS-141]* output lateral and vertical deviation data as defined in Sections 2.3.11.5.1.1 and 2.3.11.5.1.2. The equipment may optionally output lateral and vertical rectilinear deviations.

The deviation definitions are based on Final Approach Segment (FAS) data as defined in RTCA/DO-246(), illustrated in Figure 2-6, and described in Appendix C. Examples of deviation computations are also presented in Appendix C.

Note: *Deviations are defined for a Guidance Reference Point (GRP). The GRP for lateral and vertical deviations may be different. The GRP may be the* *phase-center of the GPS antenna, a fixed offset (in the along-track/vertical axes), or a separate point referenced to the aircraft.*

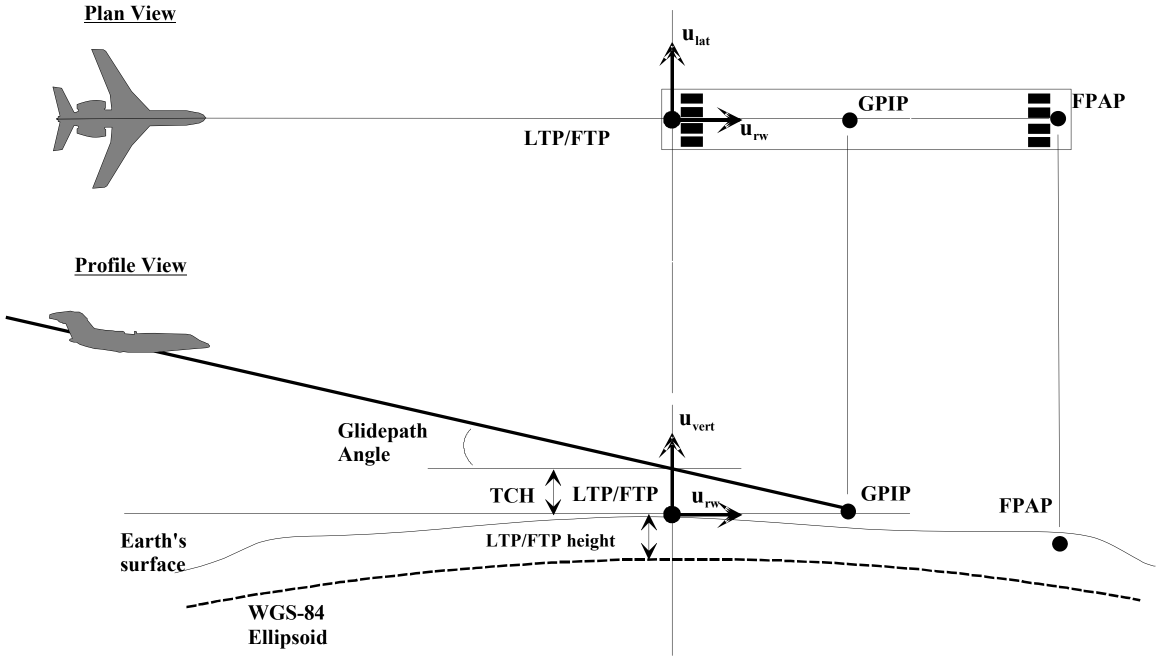


Figure 2-6 **Final Approach Segment Definition**

The PAN equipment shall *[LAAS-140]* initially output GPS/LAAS precision approach guidance information within 2 seconds following receipt of the necessary valid messages supporting the selected approach, provided all other necessary conditions are met (e.g., Sections 2.3.8.1).

When the PAN is outputting precision approach guidance information and another approach from the same GBAS station is selected, then the PAN equipment shall *[LAAS-368]* be capable of outputting precision approach guidance information for the newly selected approach within 2 seconds.

Note: *The equipment will need to store all FAS data blocks from the selected GBAS in order to provide approach guidance information within two seconds of selection of another approach from the same station.*

If the airborne equipment is providing non-numeric (analog) deviations, the electrical output shall *[LAAS-142]* have the characteristics shown in Table 2-13.

Table 2-13 Non-Numeric Electrical Output Requirements

	Requirement (% of Full-Scale)
Resolution of Electrical Output	1%
Accuracy of Centered Display	3%
Linearity of Display or Electrical Output	5%

Note: *The course derived from the broadcast FAS may be offset from the runway extended centerline. The equipment should not assume that the FAS is aligned with the runway.*

2.3.11.5.1.1 Lateral Deviations for the Approach Segment

2.3.11.5.1.1.1 Proportional Lateral Deviation

The proportional lateral deviation is defined from the following:

a) lateral deviation reference plane - the plane that contains the LTP/FTP vertical direction vector and the flight path alignment point (FPAP).

b) vertical direction vector - the vector that passes through the LTP/FTP and is normal to the WGS-84 ellipsoid at the LTP/FTP.

c) GNSS Landing System (GLS) Azimuth Reference Point (GARP) - the point that lies in the horizontal plane containing the LTP/FTP and is 305 m beyond the point where the vertical projection of the FPAP intersects this plane (See Appendix C).

Positive lateral deviations shall *[LAAS-145]* correspond to aircraft positions to the left of the lateral deviation reference plane, as observed from the LTP/FTP facing toward the FPAP.

The *final approach segment lateral deviation* is referenced to the lateral deviation reference plane, and is defined to be proportional to the angle (α_{lat}) measured at the GARP between the aircraft and the lateral deviation reference plane, with full-scale deflection (FSD) at a lateral cross-track error of:

$$\alpha_{lat,FS} = \pm \tan^{-1}\left(\frac{\text{Course Width at LTP/FTP (m)}}{\text{Distance from LTP/FTP to GARP (m)}}\right)$$

The proportional lateral deviation for precision approach shall *[LAAS-146]* be as follows:

a) On the approach side of the LTP/FTP, the deviation shall *[LAAS-148]* be the final approach segment lateral deviation;

b) Between the LTP/FTP and a point that is prior to the GARP by a distance equal to either 305 m plus the ΔLength Offset (if the ΔLength Offset parameter is provided) or 305 m (if the ΔLength Offset parameter is not provided) (typically this point will be the stop end of the runway), the deviation shall *[LAAS-149]* be either the final approach segment lateral deviation or linear (i.e., proportional to the distance from the aircraft GRP to the closest point on the lateral deviation reference plane), with FSD for a cross-track error of ±(Course Width at LTP/FTP);

c) Beyond this point (typically the stop end of the runway), the deviation output is not required. If the deviation output is provided, it shall *[LAAS-150]* have a FSD with a cross-track displacement that does not exceed ± 0.3 nmi; this deviation output may be discontinued at any point.

Note: *Item "c)" above defines a deviation output with a FSD that is not necessarily constant or linear. This requirement allows LAAS equipment to either be consistent with the SBAS and GRAS standards or to exercise additional flexibility to support other aircraft integrations and operations.*

Full-scale limits for proportional lateral deviation are illustrated in Figure 2-7.

The equipment shall *[LAAS-286]* provide proportional lateral deviation to at least twice the FSD and outside this region, the maximum output value shall *[LAAS-152]* be indicated.

Note: *Compatibility with ILS display systems can be achieved by converting the proportional lateral deviation to μA (DDM) based upon FSD at 150 μA (0.155 DDM). For aircraft positions beyond twice the FSD, the maximum output value is not limited except as constrained by the input limitations of the display instrumentation.*

2.3.11.5.1.1.2 Rectilinear Lateral Deviation

If provided, the rectilinear lateral deviation output shall *[LAAS-153]* indicate the distance from the aircraft GRP to the closest point on the lateral deviation reference plane.

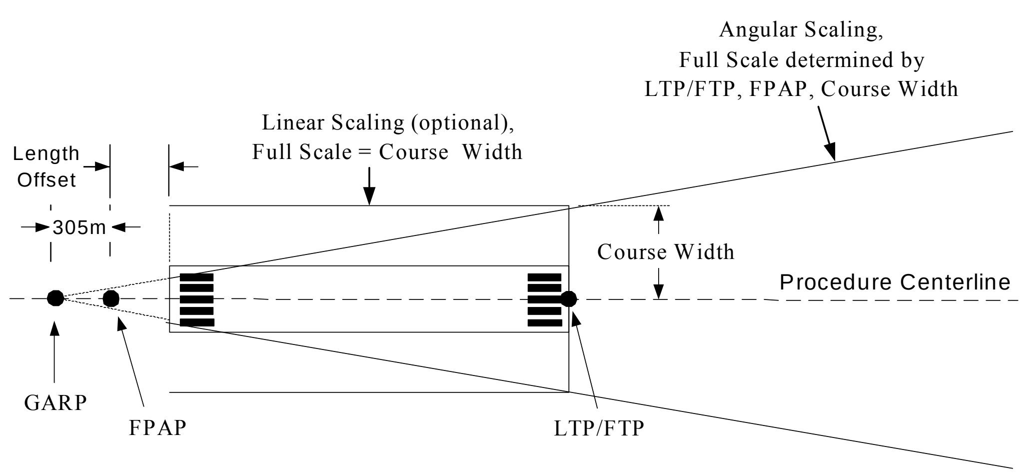


Figure 2-7 Full-Scale Deflection for Proportional Lateral Deviation

2.3.11.5.1.2 Vertical Deviations for the Approach Segment

Vertical deviations shall *[LAAS-154]* be indicated as invalid if:

a) The lateral position of the aircraft is outside of a ±35 degree wedge with origin at the GARP, centered on the FAS; or

b) The aircraft is not on the approach segment side of the Glide Path Intercept Point (GPIP).

2.3.11.5.1.2.1 Proportional Vertical Deviation

The proportional vertical deviation is defined from the following:

a) horizontal reference plane - the plane that contains the Landing Threshold Point/Fictitious Threshold Point (LTP/FTP) and is normal to LTP/FTP vertical direction vector.

b) Glide Path Intercept Point (GPIP) - the intersection of the glide path with the horizontal reference plane.

c) vertical deviation reference surface - one of the following:

(1) The conical surface containing the FAS whose apex is at the GPIP and whose axis of symmetry is parallel to the LTP/FTP vertical direction vector;

(2) A conical surface as described in [c(1)] above, but whose apex is offset up to 150 m from the GPIP in a direction normal to the lateral deviation reference plane; or

(3) A hyperbolic surface that asymptotically approaches the conical surface described in [c(1)] above, whose minimum height is not more than 8 m above the GPIP.

d) origin: the point on the vertical deviation reference surface with the minimum height above the GPIP (for c(1) and c(2) above, this point is the apex of the cone).

The *final approach segment vertical deviation* is defined to be proportional to the angle (α_{vert}) measured at the origin between the aircraft and the point on the vertical deviation reference surface that is closest to the aircraft, with full-scale deflection (FSD) for a vertical error of:

$$\alpha_{vert,FS} = \pm 0.25(\text{FAS glidepath angle})$$

The proportional vertical deviation shall *[LAAS-155]* be as follows, where the full-scale deflection for the deviation is illustrated in Figure 2-8:

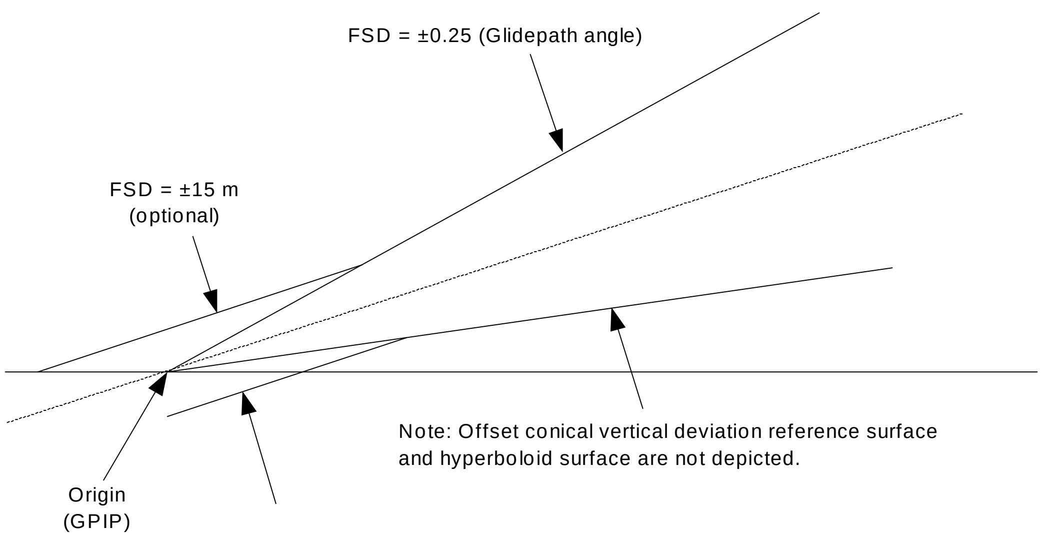
a) At a distance greater than or equal to $\frac{15m}{\tan(\alpha_{FS,vert})}$ to the origin, the deviation shall *[LAAS-157]* be the final approach segment vertical deviation;

b) Closer than $\frac{15m}{\tan(\alpha_{FS,vert})}$ to the origin, the deviation shall *[LAAS-158]* be either the final approach segment vertical deviation or linear (i.e., proportional to the distance from the aircraft GRP to the closest point on the vertical deviation reference surface) with FSD for a vertical error of ± 15 m.

Positive vertical deviations shall *[LAAS-159]* correspond to aircraft positions above the glide path.

The equipment shall *[LAAS-160]* provide proportional vertical deviation to at least twice the FSD. Outside the region of proportional guidance, the maximum output value shall *[LAAS-161]* be indicated.

<u>Note</u>: *Compatibility with ILS display systems can be achieved by converting the vertical deviation to μA (DDM) based upon FSD at 150 μA (0.175 DDM). For aircraft positions beyond twice the FSD, the maximum output value is not limited except as constrained by the input limitations of the display instrumentation.*



<u>Figure 2-8</u> Full-Scale Deflection for Proportional Vertical Deviation

2.3.11.5.1.2.2 Rectilinear Vertical Deviation

If provided, the rectilinear vertical deviation output shall *[LAAS-162]* indicate the distance from the aircraft GRP to the closest point on the vertical deviation reference surface.

2.3.11.5.1.3 Deviation Output Rate and Latency

Deviations shall *[LAAS-143]* be computed and output from dynamically independent position updates at a nominal rate of at least 5 times per second. A dynamically independent position update is one that captures aircraft acceleration that occurs after the previous computation. Position updates developed by extrapolating from previous position and velocity computations are not dynamically independent.

<u>Note</u>: *A 5-per-second update rate may not be sufficient for all aircraft installations.*

The overall latency, defined as the total delay between normal maneuver dynamic inputs (Section 2.3.3) and the completion of transmission of the deviation output reflecting the inputs, shall *[LAAS-144]* not exceed 400 msec for inputs with frequency content in the range of zero to 1 radian per second.

Notes:

1) *This metric includes the effects of tracking-loop dynamic response, computation rate, and computational latency.*

2) *The specified output latency may not be compatible with all aircraft installations.*

2.3.11.5.1.4 Missed Approach Guidance

If the PAN equipment provides missed approach guidance, the requirements in this section apply. The equipment shall *[LAAS-163]* sequence to outputting lateral deviation with linear scaling such that the FSD for a cross-track error is ± 0.3 nautical mile full-scale deflection referenced to the extended approach centerline. The vertical deviations shall *[LAAS-164]* be output as invalid for the missed approach segment.

The PAN equipment shall *[LAAS-165]* sequence to missed approach guidance based on an external input commanding missed approach. The PAN equipment shall *[LAAS-166]* automatically sequence to missed approach guidance when all of following conditions are satisfied: 1) the computed aircraft position passes the LTP/FTP (i.e., when the bearing to the LTP/FTP is more than ±90 deg from the FAS bearing), 2) the GRP height is greater than 200 feet above the LTP/FTP, and 3) the proportional vertical deviation is full-scale fly down.

Note: *In many installations, LAAS equipment will be complemented with RNAV equipment that will provide the missed approach guidance for the missed approach segment. For these aircraft, it is not required that the LAAS equipment output missed approach guidance.*

2.3.11.5.2 Alerts

2.3.11.5.2.1 Loss of Approach Guidance

The PAN equipment shall *[LAAS-167]* provide an indication when the navigation system is no longer adequate to conduct or continue the precision approach.

The lateral and vertical deviation outputs shall *[LAAS-168]* be invalidated 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) Probable equipment malfunction or failure.

2.3.11.5.2.1.1 Loss of Approach Guidance – GAST C

When the active Approach Service Type is GAST C, the lateral and vertical deviation outputs shall *[LAAS-169]* be invalidated within 0.4 seconds from the onset of any of the following conditions:

a) The lateral protection level (Section 2.3.11.5.2.1.4) or the Lateral Ephemeris Error Position Bound (Section 2.3.11.5.2.1.5) exceeds the lateral alert limit (Section 2.3.11.5.2.1.3.1);

b) The elapsed time from the receipt of any Type 1 message containing the 100-second differential corrections for the ranging sources used in the position solution (Section 2.3.8.1.2) is equal to or greater than 3.5 seconds and the aircraft is within the PAR;

c) The difference between the current time and the reference time of the corrections (derived from the modified z-count) is equal to or greater than 6 seconds and the aircraft is within the PAR.

Note: *If approach guidance is being provided, the loss of a valid differential position solution also causes the loss of valid approach guidance regardless of whether the aircraft is inside or outside the PAR.*

When the active Approach Service Type is GAST C, the vertical deviation output shall *[LAAS-170]* be invalidated within 0.4 seconds from the time the vertical protection level (Section 2.3.11.5.2.1.4) or the Vertical Ephemeris Error Position Bound (Section 2.3.11.5.2.1.5) exceeds the vertical alert limit (Section 2.3.11.5.2.1.3.2).

2.3.11.5.2.1.2 Loss of Approach Guidance – GAST D

When the active Approach Service Type is GAST D, the active Approach Service Type shall *[LAAS-369]* be invalidated within 0.4 seconds from the onset of any of the following conditions:

a) The lateral protection level (Section 2.3.11.5.2.1.4) or the Lateral Ephemeris Error Position Bound (Section 2.3.11.5.2.1.5) exceeds the lateral alert limit (Section 2.3.9.4).

b) The vertical protection level (Section 2.3.11.5.2.1.4) or the Vertical Ephemeris Error Position Bound (Section 2.3.11.5.2.1.5) exceeds the vertical alert limit (Section 2.3.9.4).

c) The elapsed time from the receipt of any Type 1 message containing the 100-second differential corrections for the ranging sources used in the position solution (Section 2.3.8.1.2) is equal to or greater than 1.5 seconds and the computed position is below 200 feet above the LTP/FTP.

d) The elapsed time from the receipt of any Type 11 message containing the 30-second differential corrections for the ranging sources used in the position solution (Section 2.3.8.1.2) is equal to or greater than 1.5 seconds and the computed position is below 200 feet above the LTP/FTP.

e) The difference between the current time and the reference time of the corrections (derived from the modified z-count) is equal to or greater than 4 seconds and the computed position is below 200 feet above the LTP/FTP.

f) The elapsed time from the receipt of any Type 1 message containing the 100-second differential corrections for the ranging sources used in the position solution (Section 2.3.8.1.2) is equal to or greater than 3.5 seconds and the computed position is 200 feet or more above the LTP/FTP.

g) The elapsed time from the receipt of any Type 11 message containing the 30-second differential corrections for the ranging sources used in the position solution (Section 2.3.8.1.2) is equal to or greater than 3.5 seconds and the computed position is 200 feet or more above the LTP/FTP.

h) The difference between the current time and the reference time of the corrections (derived from the modified z-count) is equal to or greater than 6 seconds and the computed position is 200 feet or more above the LTP/FTP.

Note: *If approach guidance is being provided, the loss of a valid differential position solution causes the loss of valid approach guidance regardless of whether the aircraft is inside or outside the PAR, and regardless of the active Approach Service Type.*

When the active Approach Service Type is invalidated the equipment shall *[LAAS-370]* either:

a) Automatically set the active Approach Service Type to a lower type of service, perform the appropriate checks (Section 2.3.11.1.3.2), and output the current status (Section 2.3.11.1.3.3); or

b) If a lower type of service is not available, invalidate the lateral and vertical deviation outputs.

2.3.11.5.2.1.3 Alert Limits

2.3.11.5.2.1.3.1 Lateral Alert Limits

When the computed position is inside the PAR and the bearing to the LTP/FTP is within +/- 90 deg of the FAS bearing, (Section 2.3.11.1.3), the lateral alert limit shall *[LAAS-171]* be as defined in Table 2-14. When the computed position is inside the PAR and the bearing to the LTP/FTP is more than +/- 90 deg of the FAS bearing, the lateral alert limit shall *[LAAS-275]* be equal to the FASLAL. When the approach has been selected and the computed position is outside of the PAR, the lateral alert limit shall *[LAAS-172]* be the sum of Final Approach Segment Lateral Alert Limit (FASLAL) and 29.15 meters.

Table 2-14 Lateral Alert Limit

Lateral alert limit (meters)	Horizontal distance of aircraft position to the LTP/FTP (D) (meters)
FASLAL (see Note)	$0 \le D \le 873$
0.0044D+FASLAL-3.85	$873 < D \le 7500$
FASLAL+29.15	$D > 7500$

Note: *FASLAL, as defined in RTCA/DO-246(), is the Lateral Alert Limit for the selected approach (see Section 2.3.4).*

2.3.11.5.2.1.3.2 Vertical Alert Limits

When the computed position is inside the PAR, the vertical alert limit shall *[LAAS-173]* be as defined in Table 2-15. When the approach has been selected and the computed position is outside of the PAR, the vertical alert limit shall *[LAAS-174]* be equal to the sum of Final Approach Segment Vertical Alert Limit (FASVAL) and 33.35 meters.

Table 2-15 Vertical Alert Limit

Vertical alert limit (meters)	**H_p (meters) (see Note 1)**
FASVAL (see Note 2)	$H_p \leq 60.96$
$0.095965H_p$+FASVAL-5.85	$60.96 < H_p \leq 408.432$
FASVAL+33.35	$H_p > 408.432$

Notes:

1) *H_p = the product of sin(GPA) [where GPA is Glide Path Angle] and the slant-range distance from the aircraft position to the GPIP.*

2) *FASVAL, as defined in RTCA/DO-246(), is the Vertical Alert Limit for the selected approach (see Section 2.3.4).*

2.3.11.5.2.1.4 Lateral and Vertical Protection Levels

LAAS equipment shall *[LAAS-179]* compute the Lateral and Vertical Protection Levels of the LAAS signal-in-space, for each Type 1 message used in the navigation solution, relative to the selected approach segment (LPL_{Apr} and VPL_{Apr}) by computing the lateral and vertical protection levels for the H_0 and H_1 hypothesis (VPL_{Apr_H0}, LPL_{Apr_H0}, VPL_{Apr_H1}, and LPL_{Apr_H1}).

$$LPL_{Apr} = \max[LPL_{Apr\_H0}, LPL_{Apr\_H1}]$$

$$VPL_{Apr} = \max[VPL_{Apr\_H0}, VPL_{Apr\_H1}]$$

The protection levels under the H_0 hypothesis are computed as follows:

$$VPL_{Apr\_H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_vert,i}\sigma_i^2} + D_V$$

$$LPL_{Apr\_H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_lat,i}\sigma_i^2} + D_L$$

where:

K_{ffmd} = multiplier (unitless) which determines the probability of fault-free missed detection, as given in Table 2-16

Table 2-16 Fault-free Missed Detection Multiplier (K_{ffmd})

K_{ffmd}		
M_{ffmd}=2	M_{ffmd}=3	M_{ffmd}=4
5.762	5.810	5.847

M[i] = number of ground subsystem reference receivers whose pseudorange measurement was used to determine the differential correction for the i^{th} ranging source used in the navigation solution. This number is determined from the B-values in the Type 1 message reference RTCA/DO-246(), in the received VDB message.

M_{ffmd} = the maximum M[i].

$s_{(),()}$ ≡ elements of the Approach Service Type dependent weighted least squares projection matrix **S** (reference Section 2.3.9.1) used in the generation of the precision approach guidance outputs (unitless)

The coordinate reference frame is defined such that the x is along-track, positive forward, y is cross-track positive left in the local level tangent plane at the LTP/FTP, and z is the positive up and orthogonal to this local level tangent plane.

$s_{1,i}$ =, the projection of the x-component for the i^{th} satellite

$s_{2,i}$ = the projection of the y-component for the i^{th} satellite

$s_{3,i}$ = the projection of the z-component for the i^{th} satellite

$s_{Apr\_vert,i} = s_{3,i} + s_{1,i} * \tan \theta_{GPA}$ = projection of the vertical component and translation of the along-track components into the vertical for i^{th} ranging source.

Note: The second term in $s_{Apr\_vert,i}$ accounts for the effect of uncertainty in the along-track position on the error in the vertical guidance output.

$s_{Apr\_lat,i} = s_{2,i}$ = projection of the lateral component for i^{th} ranging source.

θ_{GPA} = glide path angle for the final approach path

N = number of ranging sources used in the position solution

$$\sigma_i^2 = \sigma_{pr\_gnd\_x}^2[i] + \sigma_{tropo}^2[i] + \sigma_{pr\_air}^2[i] + \sigma_{iono}^2[i]$$

$\sigma_{pr\_gnd\_x}[i]$ is dependent on the active Approach Service Type. See Section 2.3.11.5.2.4.

$\sigma_{tropo}[i]$ is the residual tropospheric uncertainty (in meters) for satellite *i,* as defined in Section 2.3.12.2.

$\sigma_{pr\_air}[i]$ is the total (post correction) fault-free airborne error term (in meters) for satellite *i,* see Section 2.3.12.1.

$\sigma_{iono}[i]$ is the residual ionospheric uncertainty (in meters) for satellite *i*, computed per Section 2.3.12.3. This parameter is dependent on the active Approach Service Type, see section 2.3.11.5.2.4.

i = ranging source index

D_V = a parameter that depends on the active Approach Service Type.

For GAST C, D_V =0

For GAST D, D_V = the magnitude of the vertical projection of the difference between the 30 second smoothed position solution and the 100 second smoothed position solution (see 2.3.9.2.3)

D_L = a parameter that depends on the active Approach Service Type.

For GAST C, D_L =0.

For GAST D, D_L = the magnitude of the lateral projection of the difference between the 30 second smoothed position and the 100 second smoothed position (see 2.3.9.2.3).

The protection levels under the H_1 hypothesis are computed as follows:

$$VPL_{Apr\_H1} = \max\left[VPL_{Apr\_H1}[j]\right] + D_V$$

$$LPL_{Apr\_H1} = \max\left[LPL_{Apr\_H1}[j]\right] + D_L$$

where:

VPL_{Apr_H1}[j] and LPL_{Apr_H1}[j] for all j (1 to MAX { M[i] }) as follows:

$$VPL_{Apr\_H1}[j] = \left|B_{j\_Apr\_vert}\right| + K_{md}\sigma_{Apr\_vert\_H1}$$

$$LPL_{Apr\_H1}[j] = \left|B_{j\_Apr\_lat}\right| + K_{md}\sigma_{Apr\_lat\_H1}$$

j = ground subsystem reference receiver index

K_{md} = multiplier (unitless) which determines the probability of missed detection given that the ground subsystem is faulted, as given in Table 2-17

Table 2-17 Missed Detection Multiplier (K_{md})

K_{md}		
M_{md}=2	M_{md}=3	M_{md}=4
2.935	2.898	2.878

M_{md} = the minimum M[i]

B[i,j] ≡ reference Section 2.3.10.2

Note: *The PAN applies the value of zero for each of B value set to the bit pattern "1000 0000." This bit pattern indicates that the measurement is not available.*

$$B_{j\_Apr\_vert} = \sum_{i=1}^{N} s_{Apr\_vert,i} B[i,j]$$

$$B_{j\_Apr\_lat} = \sum_{i=1}^{N} s_{Apr\_lat,i} B[i,j]$$

$$\sigma_{i\_H1}^2 = \left(\frac{M[i]}{U[i]}\right)\sigma_{pr\_gnd\_x}^2[i] + \sigma_{tropo}^2[i] + \sigma_{pr\_air}^2[i] + \sigma_{iono}^2[i]$$

The computation of σ_{i_H1} depends on the active Approach Service Type. See section 2.3.11.5.2.4.

U[*i*] = number of ground subsystem reference receivers whose pseudorange measurements were used to determine the differential correction for the i^{th} ranging source used in the navigation solution, not counting the j^{th} reference receiver.

$$\sigma_{Apr\_vert\_H1}^2 = \sum_{i=1}^{N} s_{Apr\_vert,i}^2 \sigma_{i\_H1}^2$$

$$\sigma_{Apr\_lat\_H1}^2 = \sum_{i=1}^{N} s_{Apr\_lat,i}^2 \sigma_{i\_H1}^2$$

2.3.11.5.2.1.5 Vertical and Lateral Ephemeris Error Position Bounds

If the ephemeris error missed detection parameters are provided in the Type 2 message being used, then the PAN equipment shall *[LAAS-287]* compute the Vertical and Lateral Ephemeris Error Position Bounds for each Type 1 message used in the navigation solution, relative to the selected approach segment (VPB_{Apr_e} and LPB_{Apr_e}).

The Vertical and Lateral Ephemeris Error Position bounds are given by:

$$VPB_{Apr\_e} = \max(VPB_{Apr\_e}[k]) + D_V$$

$$LPB_{Apr\_e} = \max(LPB_{Apr\_e}[k]) + D_L$$

where:

$VPB_{Apr\_e}[k]$ is the vertical ephemeris error position bound relative to the selected approach segment for the k^{th} GPS ranging source used in the position solution, where $VPB_{Apr\_e}[k]$ is computed for all GPS ranging sources used in the position solution:

$$VPB_{Apr\_e}[k] = \left|s_{Apr\_vert,k}\right| x_{air} P_{k\_x} + K_{md\_e\_x}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_vert,i}\sigma_i^2}$$

P_{k_x} ≡ reference Section 2.3.11.5.2.4 (Approach Service Type dependent)

$s_{Apr\_vert,i}$ ≡ reference Section 2.3.11.5.2.1.4

x_{air} ≡ reference Section 2.3.10.2

σ_i ≡ Reference Section 2.3.11.5.2.1.4.

$K_{md\_e\_x}$ = the Approach Service Type dependent broadcast multiplier for computation of the ephemeris error position derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite (unitless). Reference Section 2.3.11.5.2.4.

$LPB_{Apr\_e}[k]$ is the lateral ephemeris error position bound relative to the selected approach segment for the k^{th} GPS ranging source used in the position solution, where $LPB_{Apr\_e}[k]$ is computed for all GPS ranging sources used in the position solution:

$$LPB_{Apr\_e}[k] = \left|s_{Apr\_lat,k}\right| x_{air} P_{k\_x} + K_{md\_e\_x}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_lat,i}\sigma_i^2}$$ $s_{Apr\_lat,i}$ ≡ reference Section 2.3.11.5.2.1.4

D_V = a parameter that depends on the active Approach Service Type. See section 2.3.11.5.2.1.4.

D_L = a parameter that depends on the active Approach Service Type. See section 2.3.11.5.2.1.4.

Note: *The ephemeris error position bounds are computed only for GPS satellites used in the position solution (k index) and not for other types of ranging sources (e.g., SBAS satellites) that are not subject to undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).*

2.3.11.5.2.2 Bias Approach Monitor (BAM)

The equipment shall *[LAAS-181]* perform the BAM evaluations when:

a) The computed position transitions from outside the PAR to inside the PAR, or once before outputting valid deviations if the approach is selected while the aircraft is inside the PAR,

b) Inside the PAR, if there is a change in the satellites that are used in the position solution (i.e., loss of a satellite or addition of a satellite), and

c) For Multiple Approach Service Type capable equipment, if there is a change in the active Approach Service Type when inside the PAR.

The BAM evaluations are:

$$2\sqrt{\sum_{i=1}^{N} s_{Apr\_vert,i}^{2}\sigma_i^2} + D_v \leq FASVAL \text{, and}$$

$$|B_{j\_Apr\_vert}| + D_v \leq \text{FASVAL for all j}$$

The elements of ***s*** and B are as defined in Section 2.3.11.5.2.1.4. The value of σ_i is as defined in Section 2.3.11.5.2.1.4, with the exception that the value for $\sigma_{noise}[i]$ and $\sigma_{divg}[i]$ (reference Section 2.3.12.1) can be based on the expected value after the pseudorange smoothing filter has reached steady state. D_v is defined in Section 2.3.11.5.2.1.4.

If either of the BAM evaluations fail, the vertical deviations shall *[LAAS-182]* be indicated as invalid.

<u>Note</u>: *This monitor ensures that the projection of the FAS path realized in the airborne equipment passes within a window defined by the FASVAL, with high confidence. A lateral check is not required, as the vertical check is more stringent and provides sufficient screening.*

2.3.11.5.2.3 Reference Receiver Fault Monitor (RRFM)

Equipment operating with GAST D shall *[LAAS-371]* perform the RRFM evaluations when the computed position is inside the PAR.

The RRFM evaluations are (for all *j* reference receivers):

$$|B_{j\_Apr\_vert}| + D_V \leq T_{B\_air\_vert}$$

$$|B_{j\_Apr\_lat}| + D_L \leq T_{B\_air\_lat}$$

where:

$B_{j\_Apr\_vert}$ and $B_{j\_Apr\_lat}$ are as defined in Section 2.3.11.5.2.1.4.

D_V and D_L are as defined in Section 2.3.11.5.2.1.4.

$$T_{B\_air\_vert} = K_{ffd\_B}\sqrt{\sigma_{B\_vert}^2 + \sigma_{D_V}^2}$$

$$T_{B\_air\_lat} = K_{ffd\_B}\sqrt{\sigma^2_{B\_lat} + \sigma^2_{D_L}}$$

σ_{D_V} = standard deviation of D_V

σ_{D_L} = standard deviation of D_L

Note: *The manufacturer should establish values for σ_{D_V} and σ_{D_L} to represent the actual system performance.*

$$\sigma^2_{B\_vert} = \sum_{i=1}^{N} \frac{S^2_{Apr\_vert,i\_}\sigma^2_{pr\_gnd\_100,i}}{U[i]}$$

$$\sigma^2_{B\_lat} = \sum_{i=1}^{N} \frac{S^2_{Apr\_lat,i\_}\sigma^2_{pr\_gnd\_100,i}}{U[i]}$$

S_{Apr_vert} and S_{Apr_lat} are as defined in Section 2.3.11.5.2.1.4

$\sigma^2_{pr\_gnd\_100,i}$ = GAST D total (post correction) fault-free error term (in meters) associated with the corresponding differential correction for satellite i from the Type 11 Message

K_{ffd_B} = 5.5 is a multiplier (unitless) that determines the probability of fault free detection

Note: *This value for K_{ffd_B} provides a continuity of approximately (1-10^{-7}) assuming that $B_{j\_Apr\_vert}$ and D_V are Gaussian distributed random variables.*

If either $T_{B\_air\_vert}$ or $T_{B\_air\_lat}$ is exceeded, change the active Approach Service Type to C and output appropriately per Section 2.3.11.1.3.3, or use a subset geometry for which the threshold is not exceeded.

2.3.11.5.2.4 Protection Levels - Service Type Specific Requirements

The computation of the vertical and horizontal protection levels, ephemeris error protection bounds, and BAM evaluations include parameters that depend on the active Service Type. Those parameters are the bounding sigmas, σ_i and σ_{i_H1}, and the ephemeris decorrelation parameter, P_{k_x} , and missed detection multiplier, $K_{md\_e\_x}$.

The bounding sigmas, σ_i and σ_{i_H1}, and the ephemeris error protection bounds shall *[LAAS-372]* be computed using components as indicated in Table 2-18.

Table 2-18 Service Type Dependent Parameters Used in Protection Level Calculations

Service Type	Positioning Service, GAST C	GAST D
$\sigma_{pr\_gnd\_x}$	σ_{pr_gnd} from Message Type 1	$\sigma_{pr\_gnd\_100}$ from Message Type 11
σ_{iono}	Computed per Section 2.3.12.3 using $\sigma_{vert\_iono\_gradient}$ from Message Type 2, and a time constant τ of 100 seconds	Computed per Section 2.3.12.3 using $\sigma_{vert\_iono\_gradient\_D}$ from Message Type 2 Additional Data Block 3, and a time constant τ of 100 seconds
P_{k_x}	P_k from Message Type 1	P_{k_D} from Message Type 11
$K_{md\_e\_x}$	$K_{md\ e}$ from Message Type 2	$K_{md\_e\_D}$ from Message Type 2 Additional Data Block 3

2.3.11.5.3 Distance to Threshold

The distance to threshold, defined as the horizontal distance between the aircraft position and the LTP/FTP, shall *[LAAS-183]* be computed from dynamically independent position updates.

2.3.11.5.3.1 Distance to Threshold Output

The PAN shall *[LAAS-184]* output the distance to threshold at a rate of at least once per second whenever the equipment is outputting valid lateral deviations.

2.3.11.5.3.2 Distance to Threshold Output Latency

The distance to threshold output latency, defined as from when the distance is applicable until when the distance is output, shall *[LAAS-185]* not exceed 400 msec.

2.3.12 Error Models

2.3.12.1 Model of Airborne Pseudorange Performance

The σ_{pr_air} shall *[LAAS-175]* be computed as follows:

$$\sigma_{pr\_air}[i] = (\sigma^2_{noise}[i] + \sigma^2_{multipath}[i] + \sigma^2_{divg}[i])^{1/2}$$

The installed multipath error for the airborne PAN equipment is described by the distribution, $N\left(0, \sigma^2_{multipath}\right)$ where:

$$\sigma_{multipath}[i] = 0.13 + 0.53\, e^{(-\theta[i]/10\ deg)} \text{ (in meters)}$$

$\theta[i]$ = elevation angle of satellite i (in degrees)

Note: *This multipath error model was developed and validated using flight test data collected on a variety of large, fixed-wing aircraft. Further validation was done using computer modeling of large, fixed-wing aircraft.*

$\sigma_{divg}[i]$ (in meters) shall *[LAAS-176]* be greater than or equal to the differentially-corrected pseudorange error induced by the initialization or re-initialization of the airborne smoothing filter relative to its steady-state. The code-carrier divergence rate is defined to be represented by a normal distribution with zero mean and a standard deviation of 0.018 m/s.

Note: *A constant code-carrier divergence rate of 0.018 m/sec induces a steady-state bias in the broadcast pseudorange correction of 0.018 m/s *(100 sec smoothing time constant + carrier aided code loop time constant). The code loop time constant for the ground receiver must be less than or equal to 2 sec (equivalent to noise bandwidth ≥ 0.125 Hz). Therefore the resulting steady state bias in the broadcast correction will lie in the range 1.8 m to 1.836 m. This bias produces an error in the differentially-corrected pseudorange when the airborne smoothing filter is initialized or reinitialized. The initial error decays with time as an equivalent bias is induced in the airborne smoothed pseudorange. $\sigma_{divg}[i]$ accounts for the transient deviation of the airborne filter from the ground's steady state response. The steady state component is accounted for by the LAAS Ground Facility.*

$\sigma_{noise}[i]$ (in meters) shall *[LAAS-177]* be the standard deviation of a normal distribution that bounds the errors in the tails of the distribution associated with the GNSS receiver for satellite i, including receiver noise, thermal noise, interference, inter-channel biases, extrapolation, time since smoothing filter initialization, and processing errors.

The parameter σ_{noise} must change to reflect current signal conditions. For example, degradation to system accuracy due to interference must be accounted for in the value of σ_{pr_air} that is used in the protection level computations, within the time to alert.

Note: *The test procedures of Section 2.5.3.2 are sufficient to show compliance with both the accuracy requirement in Section 2.3.6.8 and the σ_{noise} requirement for integrity. The σ_{noise} validated through those tests can be used as the standard deviation of a normal distribution that bounds the tails of the error distribution associated with the receiver tracking performance.*

The steady-state value of $\sigma_{noise}[i]$ at the minimum and maximum signal levels (Section 2.3.6.2) shall *[LAAS-292]* be as follows:

GPS Satellites Minimum signal level:

$\sigma_{noise}[i] \leq 0.36$ meters for airborne Accuracy Designator A, and

$\sigma_{noise}[i] \leq 0.15$ meters for airborne Accuracy Designator B

GPS Satellites, Maximum signal level:

$\sigma_{noise}[i] \leq 0.15$ meters for airborne Accuracy Designator A, and

$\sigma_{noise}[i] \leq 0.11$ meters for airborne Accuracy Designator B

SBAS Satellites, Minimum signal level:

$\sigma_{noise}[i] \leq 1.8$

SBAS Satellites, Maximum signal level:

$\sigma_{noise}[i] \leq 1.0$

<u>Note</u>: *These inequalities are consistent with the accuracy requirement defined in Section 2.3.6.8.*

2.3.12.2 Model of Tropospheric Residual Uncertainty

The residual tropospheric uncertainty (reference Section 2.3.8.2.1) shall *[LAAS-178]* be defined as:

$$\sigma_{tropo} = \sigma_n h_0 \frac{10^{-6}}{\sqrt{0.002 + \sin^2(\theta)}} \left(1 - e^{-\Delta h / h_0}\right)$$

where:

σ_n = refractivity uncertainty transmitted by ground subsystem in Message Type 2.

θ, Δh, and h_0 are defined in Section 2.3.8.3.

2.3.12.3 Model of Ionospheric Residual Uncertainty

The residual ionospheric uncertainty shall [LAAS-279] be defined as:

$$\sigma_{iono} = F_{PP} \times \sigma_{vert\_iono\_gradient\_x} \times \left(x_{air} + 2 \times \tau \times \nu_{air}\right)$$

where:

F_{PP} = the vertical-to-slant obliquity factor (unitless) for the given satellite and

$$F_{PP} = \left[1 - \left(\frac{R_e \cos\theta}{R_e + h_I}\right)^2\right]^{-\frac{1}{2}}$$

R_e = radius of the earth = 6378.1363 km

h_I = ionospheric shell height = 350 km
θ = the elevation angle of satellite
$\sigma_{vert\_iono\_gradient\_x}$ = the Service Type dependent standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation. Reference Sections 2.3.9.1 and 2.3.11.5.2.4.
x_{air} ≡ reference Section 2.3.10.2
τ = the Service Type dependent time constant of the smoothing filter. Reference Sections 2.3.9.1 and 2.3.11.5.2.4.
ν_{air} = the horizontal speed of the aircraft (meters/sec).

Note: *The "x_{air}" and "$2\tau\nu_{air}$" terms inside the equation for sigma_iono are the result of different ionospheric effects. The "x_{air}" term represents the difference in ionospheric slant delay between GBAS reference point and aircraft pierce points, given that the direction of the ionospheric spatial gradient is parallel to the vector between the GBAS reference point and aircraft. The "$2\tau\nu_{air}$" term represents the code-carrier divergence due to the ionospheric divergence that occurs when the aircraft traverses the ionosphere gradient over one smoothing time constant "τ.". (The factor of 2 is due to the gradient impacting pseudorange and carrier phase measurements in opposite directions.) This term assumes that the direction of the ionosphere gradient is parallel to that of the aircraft motion over the last smoothing time constant. When the aircraft is moving directly toward the LGF reference point, these two assumed gradient directions line up, and the computed σ_{iono} is a consistent bound. When the aircraft is not moving directly toward the GBAS reference point, the computed σ_{iono} is conservative because two different worst-case assumptions about the direction of the gradient are assumed at the same time. However, since the true direction of the gradient is unknown, the use of this conservative bound is appropriate in all cases.*

2.4 Equipment Performance Environmental Conditions

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual operations.

The environmental performance requirements identified in this section must be met for all components in the airborne GPS/LAAS system.

Some of the environmental tests contained in this subsection need not be performed unless the manufacturer wishes to qualify the equipment for a particular environmental condition. The unshaded rows of Table 2-19 through Table 2-21 identify the environmental tests that are required to qualify VDB equipment, VDB antennas, and PAN equipment respectively. The shaded rows identify optional environmental tests to be performed if the manufacturer wishes to qualify the equipment for these additional environmental conditions. An "X" in a cell of Table 2-19 through Table 2-21 identifies a requirement that must be met under the environmental test condition specified.

Unless otherwise specified, the pass/fail criteria are those specified in the test procedures applicable to the requirements listed in the tables, as modified by

Section 2.4.1.1. The test procedures applicable to a determination of equipment performance under environmental test conditions are set forth in RTCA Document DO-160F, *Environmental Conditions and Test Procedures for Airborne Equipment*.

Some of the performance requirements in Sections 2.2 and 2.3 are not required to be tested under all of the conditions contained in RTCA/DO-160F. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Sections 2.2 and 2.3 will not be measurably degraded by exposure to these conditions.

2.4.1 Environmental Tests

RTCA/DO-160F contains equipment categories for each environmental condition with different environmental test limits for each category. The equipment manufacturer is allowed to choose which environmental category the article is to be qualified, except for Lightning and Radio Frequency Susceptibility tests, for which a minimum test level is specified. The manufacturer's certification must specifically state the environmental categories for which the article is qualified.

2.4.1.1 VDB Required Performance

Table 2-19 shows matrix chart that defines the tests required for VDB equipment while Table 2-20 shows the matrix that defines the test required for the VDB antenna. These tables identify the paragraph numbers in RTCA/DO-160F that describe the individual environmental tests. These tests must be performed on the test article as specified.

The following sections state procedure requirements for demonstrating the VDB performance requirements in Table 2-19.

Table 2-19 VDB Environmental Performance Requirements

NA	2.2.8.1			2.2.5	**MOPS Section**	
System Operating	1st Adjacent Channel			Message Failure Rate	Requirement	
					Section	**DO-160F Requirement**
	X			X	4.5.2	Low Operating Temperature Test
				X	4.5.3	High Short-Time Temperature Test
	X			X	4.5.4	High Operating Temperature Test
				X	4.5.5	In-Flight Loss of Cooling
				X	4.6.1	Attitude Test
				X	4.6.2	Decompression Test
				X	4.6.3	Overpressure Test
				X	5	Temperature Variation Test
				X	6	Humidity Test
				X	7.2	Shock Test - Operational Shocks
					7.3	Shock Test - Crash Safety Shocks
				X	8	Vibration Test
X					9	Explosion Proofness Test
				X	10.3.1	Waterproofness – Condensing Water Proof Test
				X	10.3.2	Waterproofness - Drip Proof Test
				X	10.3.3	Waterproofness - Spray Proof Test
				X	10.3.4	Waterproofness - Cont. Stream Test
				X	11.4.1	Fluid Suscept. Test - Spray Test
				X	11.4.2	Fluid Suscept. Test - Immersion Test
				X	12	Sand and Dust Test
				X	13	Fungus Resistance Test
				X	14	Salt Fog Test
X					15	Magnetic Effect Test
				X	16.5.1 & 2	Power Input Test - Normal /Abnormal Op. Cond. (AC)
				X	16.6.1 & 2	Power Input Test – Normal/Abnormal Op. Cond. (DC)
				X	17	Voltage Spike Conducted Test
				X	18	Audio Freq. Conducted Suscept. Test
				X	19	Induced Signal Suscept. Test
				X	20	RF Susceptibility Test
X					21	Emission of RF Energy Test
				X	22	Lightning Induced Trans. Suscept. Test
				X	23	Lightning Direct Effects Test

NA System Operating	2.2.8.1 1st Adjacent Channel			2.2.5 Message Failure Rate	**MOPS Section** Requirement	
				X	24	Icing Test
				X	25	Electrostatic Discharge
					26	Fire, Flammability

Table 2-20 VDB Antenna Performance Requirements

2.2.10.2.2.2 Antenna VSWR (Vert)	2.2.10.2.1.2 Antenna VSWR (Horz)	**MOPS Section** Requirement	
		Section	**DO-160F Requirement**
		4.5.2	Low Operating Temperature Test
		4.5.3	High Short-Time Temperature Test
		4.5.4	High Operating Temperature Test
		4.5.5	In-Flight Loss of Cooling
		4.6.1	Attitude Test
		4.6.2	Decompression Test
		4.6.3	Overpressure Test
		5	Temperature Variation Test
		6	Humidity Test
		7.2	Shock Test - Operational Shocks
		7.3	Shock Test - Crash Safety Shocks
		8	Vibration Test
		9	Explosion Proofness Test
X	X	10.3.1	Waterproofness – Condensing Water Proof Test
X	X	10.3.2	Waterproofness - Drip Proof Test
X	X	10.3.3	Waterproofness - Spray Proof Test
X	X	10.3.4	Waterproofness - Cont. Stream Test
X	X	11.4.1	Fluid Suscept. Test - Spray Test
X	X	11.4.2	Fluid Suscept. Test - Immersion Test
X	X	12	Sand and Dust Test
X	X	13	Fungus Resistance Test
X	X	14	Salt Fog Test
		15	Magnetic Effect Test
		16.5.1 & 2	Power Input Test – Normal/Abnormal Op. Cond. (AC)
		16.6.1 & 2	Power Input Test – Normal/Abnormal Op. Cond. (DC)
		17	Voltage Spike Conducted Test
		18	Audio Freq. Conducted Suscept. Test
		19	Induced Signal Suscept. Test
		20	RF Susceptibility Test
		21	Emission of RF Energy Test
X	X	22	Lightning Induced Trans. Suscept. Test
X	X	23	Lightning Direct Effects Test
X	X	24	Icing Test

2.2.10.2.2.2 Antenna VSWR (Vert)	2.2.10.2.1.2 Antenna VSWR (Horz)	**MOPS Section** Requirement	
X	X	25	Electrostatic Discharge
		26	Fire, Flammability

2.4.1.1.1 Antenna Test

The requirements of this section are not intended to preclude the use of antennas previously approved under other RTCA MOPS requirements (and associated TSO certifications) for antennas used in other airborne radio system applications in the same frequency range addressed herein.

2.4.1.1.2 System Accuracy

The "System Operating" column in Table 2-19 and Table 2-20 exists for the environmental tests that require the system to simply be powered and operational while the environmental test is being performed.

2.4.1.2 PAN Required Performance

Table 2-21 shows a matrix chart that defines the tests required for PAN equipment. The table identifies the paragraph numbers in RTCA/DO-160F that describe the individual environmental tests. These tests must be performed on the test article as specified.

The following sections state performance requirements for demonstrating PAN performance requirements stated in Table 2-21.

Table 2-21 **PAN** Environmental Performance Requirements

						2.3.10.5	NA	2.3.6.8	2.3.6.4.4	2.3.6.4.3		2.3.6.2	**MOPS Section**	
						Velocity Accuracy	System Operating	Accuracy	Reacquisition Time	Acquisition Time		Sen. & Dynamic Range	**Requirement**	
													Section	**DO-160F Requirement**
								X				X	4.5.2	Low Operating Temperature Test
								X				X	4.5.3	High Short-Time Temperature Test
								X				X	4.5.4	High Operating Temperature Test
								X				X	4.5.5	In-Flight Loss of Cooling
								X				X	4.6.1	Attitude Test
								X				X	4.6.2	Decompression Test
								X				X	4.6.3	Overpressure Test
								X				X	5	Temperature Variation Test
								X				X	6	Humidity Test
								X				X	7.2	Shock Test - Operational Shocks
													7.3	Shock Test - Crash Safety Shocks
								X				X	8	Vibration Test
												X	9	Explosion Proofness Test
								X				X	10.3.1	Waterproofness – Condensing Water Proof Test
								X				X	10.3.2	Waterproofness - Drip Proof Test
								X				X	10.3.3	Waterproofness - Spray Proof Test
								X				X	10.3.4	Waterproofness - Cont. Stream Test
								X				X	11.4.1	Fluid Suscept. Test - Spray Test
								X				X	11.4.2	Fluid Suscept. Test - Immersion Test
								X				X	12	Sand and Dust Test
								X				X	13	Fungus Resistance Test
								X				X	14	Salt Fog Test
							X						15	Magnetic Effect Test
						X		X	X			X	16.5.1 & 2	Power Input Test - Normal/Abnormal Op. Cond. (AC)
								X		X		X	16.6.1 & 2	Power Input Test – Normal/Abnormal Op. Cond. (DC)
								X				X	17	Voltage Spike Conducted Test
								X				X	18	Audio Freq. Conducted Suscept. Test
								X				X	19	Induced Signal Suscept. Test
								X				X	20	RF Susceptibility Test
							X						21	Emission of RF Energy Test
								X		X		X	22	Lightning Induced Trans. Suscept. Test

						2.3.10.5	NA	2.3.6.8	2.3.6.4.4	2.3.6.4.3		2.3.6.2	**MOPS Section**	
						Velocity Accuracy	System Operating	Accuracy	Reacquisition Time	Acquisition Time		Sen. & Dynamic Range	**Requirement**	
								X		X		X	23	Lightning Direct Effects Test
								X	X			X	24	Icing Test
								X				X	25	Electrostatic Discharge
													26	Fire, Flammability

2.4.1.2.1 Accuracy

The demonstration of accuracy while subjecting the equipment to the environmental tests described in RTCA/DO-160F must be done in accordance with Section 2.5.3.2 of this MOPS only for the broadband external interference noise scenarios. For all other environmental tests except temperature tests (RTCA/DO-160F, Section 4.5.1 and 4.5.3), the procedure will not need to last longer than the minimum duration of the particular test as specified in RTCA/DO-160F. The test threshold is the 125% PASS THRESHOLD column in Table 2-49 and has been defined to yield an 80% probability of failing equipment with a true accuracy of 125% of the required accuracy.

Accuracy demonstrations must be performed to the tightest requirement for the accuracy designation of the equipment.

Note: *For all environmental tests except temperature, only the broadband external interference noise test case using minimum satellite power will be executed unless the minimum duration of the particular test as specified in RTCA/DO-160F allows enough time to also execute the maximum satellite power case. In particular, the RF signal susceptibility tests per section 2.4.1.3.3 only use the minimum satellite power.*

2.4.1.2.2 Sensitivity and Dynamic Range

Demonstration of this requirement should be done in conjunction with demonstration of accuracy.

2.4.1.2.3 System Operating

The "System Operating" row in Table 2-21 exists for the environmental tests that require the system to simply be powered and operational while the environmental test is being performed.

2.4.1.3 Clarification of Environmental Tests

The following paragraphs provide additional guidance for the environmental tests described in RTCA/DO-160F.

2.4.1.3.1 Power Input Tests

When Normal Operating Conditions Tests, outlined in RTCA/DO-160F Sections 16.5.1 and 16.5.2, are being performed, the equipment shall *[LAAS-186]* operate without interruption, such that the accuracy requirement shall *[LAAS-187]* continue to be met.

When Abnormal Operating Conditions Tests, identified in RTCA/DO-160F Sections 16.5.3 and 16.5.4, are being performed, the equipment is not required to operate normally during the specified minimum voltage period, but shall *[LAAS-188]* not provide misleading information neither during nor after the test.

2.4.1.3.2 Icing Tests

Icing tests have been specified primarily for the antenna(s) portion of the GPS/LAAS equipment. They are required to be conducted only if the manufacturer wants to qualify the antenna as part of the GPS/LAAS equipment. If an antenna is used that already has been qualified in this area, this environmental test is not required.

2.4.1.3.3 RF Susceptibility Tests

The GPS/LAAS equipment shall *[LAAS-189]* be qualified at least to equipment Category T of Section 20 of RTCA/DO-160F for conducted and radiated radio frequency susceptibility. The high level radiated susceptibility does not apply between 1500 MHz and 1640 MHz.

To limit test time during the frequency scans of Sections 19.3.2 and 20, the accuracy test can be run on the aggregate data and repeated only at the frequencies of greatest susceptibility. The frequencies of greatest susceptibility should be determined by at least the following two methods. First, by inspection of the receiver design, the most susceptible frequencies are identified. Second, the value of pseudorange error during the test will be compared to the standard deviation (not RMS) of the error during the scan and the frequencies with errors that deviate significantly from the aggregate are identified. The identification of frequencies can be made over sub-regions of the full frequency range as convenient given the set-up changes required when switching frequency bands; in this case, the aggregate data will be evaluated over each sub-region. Full accuracy tests are run at each of the specific frequencies identified by both methods for each type of test (conduction, radiated, and induced susceptibility).

Alternatively, the C/No (or the σ_{noise}) can be monitored to determine susceptibility as long as frequency dwell time is sufficient to detect the effect.

In addition, the GPS equipment shall *[LAAS-190]* provide the required accuracy when subjected to a radiated signal with continuous wave modulation at a frequency of 1.57542 GHz and an electric field strength of 20 mV/meter measured at the exterior case of the GPS receiver. The radiated susceptibility test procedures of RTCA/DO-160F, Section 20, should be followed when conducting this test. The test should be conducted with simulated inputs including data broadcast and appropriate ranging sources. During this test, the GPS/LAAS equipment should not experience loss of the data broadcast or loss of track with any ranging source used for navigation. The duration of the test must be sufficient to determine if tracking has been lost; 20 seconds should normally be long enough, depending on the coasting features used by the GPS/LAAS equipment.

2.4.1.3.4 Lightning Induced Transient Susceptibility Tests

The GPS/LAAS equipment shall *[LAAS-191]* at least be qualified with an appropriate waveform set and test level from Section 22 of RTCA/DO-160F for lightning induced transient susceptibility. The waveform set and test level must be sufficient to account for the induced currents and voltages caused by the lightning direct effects testing of the GPS/LAAS antenna(s) specified to be used with the equipment by the manufacturer. The equipment is not required to operate normally during the lightning transient test and must automatically become operational within the specified reacquisition time requirement.

2.4.1.3.5 Lightning Direct Effects Tests

Lightning Direct Effects Tests outlined in Section 23 of RTCA/DO-160F are required for the antenna. The antenna(s) should function normally after the lightning direct effect tests have been conducted.

Note: *Because of GPS/LAAS antenna mounting requirements, the antenna should be qualified for mounting in at least Lightning Zone 2A.*

2.4.1.3.6 Crash Safety Shock

All equipment shall *[LAAS-193]* pass the crash safety shock test as specified in RTCA/DO-160F, Section 7.3. Applicants shall *[LAAS-194]* select the aircraft type and the appropriate shock levels to which they wish to qualify their equipment.

2.5 Equipment Test Procedures

2.5.1 Definition of General Test Terms and Conditions

The subsequent sections give the definitions of terms and conditions for applicable equipment test.

2.5.1.1 Power Input Voltage

Direct Current - Unless otherwise specified, when the equipment is designed for operation from a direct current power source, all measurements shall *[LAAS-195]* be conducted with the input voltage adjusted to 13.75 V ±2% for 12-14 V equipment, or to 27.5 V ±2% for 24-28 V equipment. The input voltage shall *[LAAS-196]* be measured at the receiver power input terminals.

Alternating Current - Unless otherwise specified, when the equipment is designed for operation from an alternating current power source, all tests shall

[LAAS-197] be conducted with the power input voltage adjusted to design voltage ±2%. In the case of equipment designed for operation from a power source of essentially constant frequency (e.g., 400 Hz), the input frequency shall *[LAAS-198]* be adjusted to design frequency ±2%.

2.5.1.2 Power Input Frequency

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 *[LAAS-199]* be adjusted to design frequency ± 2 percent.

In the case of equipment designed for operation from an AC power source of variable frequency (e.g., 300-1000 Hz), unless otherwise specified, the test shall *[LAAS-200]* be conducted with the input frequency adjusted to within ± 5 percent of a selected frequency and within the range for which the equipment is designed.

2.5.1.3 RF Signal Levels

All RF signal levels are expressed in decibels with respect to one milliwatt (dBm) on a nominal 50 ohm basis. A 6 dB attenuator is explicitly shown in all test configurations to account for any impedance mismatch within the test configuration. The signal levels are generally specified at the input to the unit under test. Care should be taken to account for signal losses due to couplers, signal splitter/combiners, cables, and attenuators.

2.5.1.4 Adjustment of Equipment

The circuits of the equipment under test shall *[LAAS-201]* be aligned and adjusted in accordance with the manufacturer's recommended practices prior to the application of the specified tests.

2.5.1.5 Test Instrument Precautions

Due precautions shall *[LAAS-202]* be taken during the tests to prevent the introduction of errors or misleading data resulting from the connections of voltmeters, oscilloscopes and other test instruments across the input and output impedance of the equipment under test.

2.5.1.6 Ambient Conditions

Unless otherwise specified, all tests shall *[LAAS-203]* be conducted under the conditions of ambient room temperature, pressure and humidity. However, room temperature shall *[LAAS-289]* not be lower than 10 degrees Celsius.

2.5.1.7 Warm-Up

Unless otherwise specified, all tests shall *[LAAS-204]* be conducted after the manufacturer's specified warm-up period.

2.5.1.8 Connected Loads

Unless otherwise specified, all tests shall *[LAAS-205]* be conducted with the equipment connected to loads having the impedance values for which it is designed.

2.5.1.9 EMI Testing

Only the receiver (not the test equipment) need be subjected to the specified electromagnetic environment.

2.5.1.10 Analysis

Analysis is the method of verification which consists of comparing hardware or software design with known scientific and technical principles, technical data, or procedures and practices to validate that the proposed design will meet the specified functional or performance requirements.

2.5.1.11 Demonstration

Demonstration is the method of verification where qualitative versus quantitative validation of a requirement is made during a dynamic test of the equipment. In general, software functional requirements are validated by demonstration since the functionality must be observed through some secondary media.

2.5.1.12 Inspection

Inspection is the method of verification to determine compliance with specification requirements and consists primarily of visual observations or mechanical measurements of the equipment, physical location, or technical examination of engineering support documentation.

2.5.1.13 Test

Test is the method of verification that will measure the equipment's performance under specific configuration load conditions and after the controlled application of known stimuli. Quantitative values are measured, compared against previous predicated success criteria and then evaluated to determine the degree of compliance.

The following subsections define some of the minimum test procedures required to substantiate the minimum operational performance required for sensors using GPS/LAAS. Alternative procedures may be used if they provide an equivalent evaluation of the GPS/LAAS equipment. These test procedures assume the GPS/LAAS equipment is compliant with the minimum standard, and no additional augmentations (e.g., inertial aiding) are incorporated.

Note: *This document does not define all of the tests required to demonstrate compliance with functional requirements. Test procedures have been defined where guidance is necessary to establish the criteria for compliance with performance requirements.*

2.5.1.14 Test Cross Reference Matrix

The test cross reference matrices for the GPS/LAAS equipment bench test procedures are shown in Table 2-22. This table includes all the functional and performance requirements (shalls) contained in Sections 2.1 through 2.3. The 'shall' numbers are not necessarily in numerical sequence due to requirements being added or deleted as the document has evolved. Appendix B lists requirements, by requirements number, that have changed from prior versions of this document. It also indicates requirements that have been added. This table includes information on (1) the requirement paragraph, (2) the LAAS requirement designator, (3) the corresponding test paragraph, (4) the proposed test method (where Analysis = A, Demonstration = D, Inspection = I, and Test = T as defined above), (5) a concise version of the requirement, and (6) the pass/fail criteria for each test. The paraphrased version of the requirements in column five is provided as a quick reference for the requirement and does not replace or supersede the actual requirements. The "Test Method" column indicates the test methods that may be used to verify that the requirement has been met.

Table 2-22 Test Cross-Reference Matrix

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.1 General GPS/LAAS Airborne Requirements	[290]	—	D, I, T	Equipment outputs precision approach guidance	Requirement met
"	[291]	—	D, I, T	Equipment outputs position, velocity, and time	Requirement met
"	[068]	(Note 1)	A, D, I, T	When DCPS is supported and slant range to GRP ≤ Dmax, the PVT outputs meet either: 1) Section 2.3, 2) DO-229(), or 3) applicable RTCA GPS receiver MOPS standard	Equipment is compliant with referenced specification
"	[069]	(Note 1)	A, D, I, T	When DCPS is not supported or slant range to GRP > Dmax, the PVT outputs meet either DO-229(), or applicable RTCA GPS receiver MOPS standard	Equipment is compliant with referenced specification
2.1.1 Airworthiness	[001]	—	A, I	Equipment does not impair airworthiness	Requirement met
2.1.2 Intended Function	[002]	2.5 (all sub-sections)	A, D ,I, T	Equipment performs its intended functions	Requirements met
2.1.3 Fire Protection	[003]	—	A, I	Equipment materials are self-extinguishing	Appropriate materials used
2.1.4 General Human Factors	[004]	—	A, D, I	Controls and displays meet human factors requirements	Requirements met
2.1.4.1 Operation of Controls	[005]	—	D, I	Controls used in flight cannot be operated in a manner that would be detrimental to the equipment or to aircraft operation	Requirement met
2.1.4.2 Accessibility of Controls	[006]	—	D, I	Controls accessible without interfering with visibility of critical displays	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
“	[007]	—	D, I	Controls provide clear tactile or visual feedback when operated	Requirement met
“	[008]	—	D, I	Controls movable without excessive effort	Requirement met
“	[009]	—	D, I	Controls detents well defined	Requirement met
“	[010]	—	D, I	Control design avoids inadvertent activation	Control spacing, size and logic meet requirement
“	[011]	—	D, I	Controls operable using only one hand	Requirement met
“	[012]	—	I	Controls that need not be adjusted in flight are inaccessible	No such controls are accessible
2.1.4.3 Control Labels	[013]	—	D, I	Labels readable from specified distance	Readability acceptable at specified distance
2.1.4.4 Equipment Operating Procedures	[014]	—	I	Use of prompting cues is consistent	Requirement met
2.1.4.5 Minimum Workload Functions	[015]	—	D, I	Functions are selectable without simultaneous use of two or more controls	Requirement met
“	[016]	—	D, I	Approach is selectable without exceeding number of action and time requirements	Requirement met
2.1.4.6.1Discriminability	[017]	—	A, D, I	Alerts, alarms, and symbols are distinct and discriminable	Requirement met
“	[018]	—	A, D, I	Functions are clearly distinguishable for multi-function controls	Requirement met
2.1.4.6.2 Brightness, Contrast, and Color	[019	—	A, D, I	Displays are readable	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
“	[020]	—	A, D, I	Colors on displays are discriminable	Requirement met
“	[021]	—	I	Red is not used for other than warnings	Requirement met
“	[022]	—	I	Amber is not used for other than cautions	Requirement met
2.1.4.6.3 Angle of Regard	[023]	—	I	Displays are viewable within specified range of horizontal viewing angle	Display viewable
“	[024]	—	I	Displays are viewable within specified range of vertical viewing angle	Display viewable
2.1.4.6.5 Alphanumerics	[025]	—	A, I	Primary alphanumeric data are visible from specified distance	Alphanumerics visible
2.1.4.7 Annunciations	[026]	—	A	Annunciations are consistent with criticality of annunciation	Requirement met
“	[027]	—	A, I	Annunciations are readable	Requirement met
“	[028]	—	A I	Visual annunciations do not reduce dark adaptation	Requirement met
2.1.4.7.1 Annunciators	[029]	—	D, I	Brightness of annunciators is controllable	Requirement met
“	[030]	—	D, I	Equipment is capable of testing all external annunciators	Requirement met
2.1.4.7.2 Pilot Indications	[031]	—	A, D, I	The current indication for each urgency level is accessible	Requirement met
2.1.5 Effects of Test	[032]	—	I, A	Equipment is not adversely affected by these test procedures	Equipment is not damaged by tests
2.2.1 VDB General Requirements	[033]	—	T	Meet requirements using the standard VDB test signal	Requirements met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.2.1.1 Design Assurance	[034]	—	A, I	Hardware and software design allows installed equipment to meet an integrity and continuity allocation that supports the total system integrity and continuity requirements	Safety assessment indicates total system integrity and continuity requirements met
2.2.2.1 Frequency Range	[035]	2.5.2.2.2.1	D	VDB receiver can tune to the specified frequencies	Equipment tunes to all channels
2.2.2.2 Frequency Selection	[036]	—	I	Equipment accepts frequency or channel input	Requirement met
"	[037]	2.5.2.2.2.2	D	If the equipment accepts channel number, it converts it to frequency correctly	Requirement met
"	[038]	—	D	VDB receiver does not tune to frequencies outside the specified range	Requirement met
2.2.2.3 Response Time	[039]	2.5.2.2.2.3	T	VDB receiver outputs message data within the required time after switching frequencies	Data output within required time
2.2.3 Data Latency	[040]	2.5.2.2.3	T	Antenna-to-output latency is less than the specified time	Message latency meets requirement
2.2.4 Data Format Decoding	[041]	2.5.2.2.4	T	Properly demodulate and decode VDB signal	Message bits decoded properly
2.2.5 Message Failure Rate	[042]	2.5.2.2.5	T	Meet specified message failure rate requirement under specified nominal power level conditions	Meet specified message failure rate
"	[051]	—	T	Meet specified message failure rate requirement given large frame to frame power variations in a given time slot	Meet specified message failure rate
2.2.6.1 Carrier Frequency Capture Range	[045]	2.5.2.2.6.1	T	VDB receiver acquires and tracks signal that is offset from the nominal assigned frequency	Meet specified message failure rate

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.2.6.2 Carrier Frequency Slew Rate	[046]	2.5.2.2.6.2	T	VDB receiver acquires and tracks signal with changing carrier frequency	Meet specified message failure rate
2.2.6.3 Symbol Rate Tolerance	[047]	2.5.2.2.6.3	T	VDB receiver acquires and tracks signal over a specified range of symbol rates	Meet specified message failure rate
2.2.7.1 Co-Channel Rejection, VDB Undesired	[052]	2.5.2.2.7.1	T	Equipment provides appropriate rejection of co-channel interference, VDB	Meet specified message failure rate
2.2.7.2 Co-Channel Rejection, VOR Undesired	[053]	2.5.2.2.7.2	T	Equipment provides appropriate rejection of co-channel interference, VOR	Meet specified message failure rate
2.2.7.3 Co-Channel Rejection, LOC Undesired	[054]	2.5.2.2.7.3	T	Equipment provides appropriate rejection of co-channel interference, ILS localizer	Meet specified message failure rate
2.2.8.1 Adjacent Channel Rejection, 1st adjacent	[055]	2.5.2.2.8	T	Equipment provides rejection to adjacent channels emissions, 1st adjacent	Meet specified message failure rate
2.2.8.2 Adjacent Channel Rejection, 2nd adjacent	[056]	2.5.2.2.8	T	Equipment provides rejection to adjacent channels emissions, 2nd adjacent	Meet specified message failure rate
2.2.8.3 Adjacent Channel Rejection, 3rd adjacent and beyond	[057]	2.5.2.2.8	T	Equipment provides rejection to adjacent channels emissions, 3rd adjacent and beyond	Meet specified message failure rate
2.2.9.1 VDB Interference Immunity	[058]	2.5.2.2.9.1	T	Equipment meets requirements in the presence of the specified interference	Meet specified message failure rate
2.2.9.2.1 FM Immunity, Desensitization	[269]	2.5.2.2.9.2.1	T	Equipment meets requirements in the presence of specified FM broadcast signals	Meet specified message failure rate
2.2.9.2.2 FM Immunity, Intermodulation Rejection	[059]	2.5.2.2.9.2.2	T	Equipment meets requirements in presence of the specified intermodulation products	Meet specified message failure rate

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.2.9.3 Burn-Out Protection	[060]	—	T	Equipment survives without damage an input signal of the specified level and frequency	Equipment survives input
2.2.10.1 Receiver VSWR	[061]	2.5.2.2.10.1	T	Receiver input VSWR does not exceed specified limit	Measured VSWR meets requirement
2.2.10.2.1.1 Horizontal Antenna Gain	[062]	2.5.2.2.10.2.1.1	T	Antenna meets minimum gain requirements in the forward and rearward directions with respect to standard horizontal dipole.	Measured gains meet requirement
“	[063]	2.5.2.2.10.2.1.1	T	Antenna gain meets requirement on maximum difference between minimum and maximum gain.	Measured gains meet requirement
2.2.10.2.1.2 Horizontal Antenna VSWR	[064]	2.5.2.2.10.2.1.2	T	VSWR produced by antenna on transmission line does not exceed specified limit	Measured VSWR meets requirement
2.2.10.2.2.1 Vertical Antenna Gain	[065]	2.5.2.2.10.2.2.1	T	Antenna meets minimum gain requirements with respect to standard vertically polarized monopole antenna	Measured gains meet requirement
“	[066]	2.5.2.2.10.2.2.1	T	Antenna meets requirement on maximum difference between minimum and maximum gains	Measured gains meet requirement
2.2.10.2.2.2 Vertical Antenna VSWR	[067]	2.5.2.2.10.2.2.2	T	VSWR produced by antenna on transmission line does not exceed specified limit	Measured VSWR meets requirements
2.3.2 Design Assurance	[070]	—	A	Hardware and software design allows installed equipment to meet an integrity and continuity allocation that supports the total system integrity and continuity requirements	Safety assessment indicates total system integrity and continuity requirements met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.3 Interference and Dynamics Environment	[071]	—	A, T	Equipment meets performance requirements in presence of specified interference environment, and when exposed to normal aircraft dynamics	Equipment meets requirements under specified conditions
2.3.4 Approach and Reference Station Selection	[072]	—	I	PAN pilot interface accepts channel numbers in a specified range	Requirement met
“	[073]	—	I	PAN without pilot interface accepts a channel number input or RPDS and RSDS inputs	Requirement met
2.3.5 Reference Data Selectors and Frequency Mapping	[074]	—	D	If the equipment accepts a channel number, it converts it to an RPDS or RSDS correctly	Requirement met
“	[075]	—	D	If the equipment accepts a channel number, it converts it to a VDB frequency correctly	Requirement met
2.3.6.1 Ranging Sources	[076]	—	D, I	Equipment automatically selects ranging sources	Requirement met
“	[268]	—	D	Equipment uses GPS satellites	Requirement met
“	[077]	—	D	AEC D Equipment simultaneously tracks and decodes 10 GPS ranging sources	Requirement met
“	[318]	—	D	AEC D Equipment simultaneously tracks and decodes 12 GPS ranging sources	Requirement met
“	[316]	—	A, D, I, T	Equipment when supporting GAST C or positioning service selects GPS satellites above 5 degree mask angle according to specified criteria	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.6.2 Sensitivity and Dynamic Range	[293]	—	I	Equipment interoperable with active antenna meeting requirements in RTCA/DO-301	Documentation validates requirements met
"	[294]	—	I	Equipment interoperable with non-standard antennas validated according to RTCA/DO-301	Documentation validates requirements met
"	[295]	2.5.3.2	T	Equipment using generic active antenna accommodates GPS & SBAS signals at specified minimum and maximum power	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated
"	[296]	2.5.3.2	T	Equipment using generic active antenna tracks GPS and optionally SBAS satellites at the specified minimum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
"	[297]	2.5.3.2	T	Equipment using generic active antenna tracks GPS satellites at the specified maximum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated
"	[298]	2.5.3.2	T	Equipment using generic active antenna and using SBAS ranging tracks SBAS satellites at the specified maximum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated
"	[299]	2.5.3.2	T	Equipment using specific active antenna accommodates GPS & SBAS signals at specified minimum and maximum power	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
"	[300]	2.5.3.2	T	Equipment using specific active antenna tracks GPS and optionally SBAS satellites at the specified minimum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated
"	[301]	2.5.3.2	T	Equipment using specific active antenna tracks GPS satellites at the specified maximum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated
"	[302]	2.5.3.2	T	Equipment using specific active antenna and using SBAS ranging tracks SBAS satellites at the specified maximum input power in the presence of sky and antenna thermal noise and interference	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement; equipment operates with preamp at the minimum and maximum signal power, specified interference; min and max installation losses validated

Requirement Paragraph	Desig- nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.6.3 Equipment Burnout-Protection	[084]	—	T	Equipment withstands without damage a CW input signal of the specified level and frequency	Equipment withstands input
2.3.6.4 GPS Signal Processing	[085]	—	D	PAN processes GPS signals and data described in SPS specification	Signal tracked and data decoded
"	[086]	—	D, T	PAN does not apply an ionospheric correction	Uncorrected pseudorange outputs include entire iono delay
"	[087]	—	D, T	PAN does not apply a GPS tropospheric correction	Uncorrected pseudorange outputs include entire tropo delay
"	[088]	—	D	PAN continues to decode ephemeris and clock corrections for all ranging sources used in the navigation solution	Requirement met
"	[089]	—	D	PAN retains multiple sets of ephemeris and clock correction parameters so that corrections can be applied after IOD changes	Requirement met
"	[090]	—	I	PAN applies the clock correction after smoothing of the pseudorange	Requirement met
2.3.6.4.1 GPS Tracking Constraints	[303]	—	I	Equipment uses either E-L or DD DLL discriminators	Requirement met
"	[091]	—	A, I	Equipment with E-L DLL discriminators meets the design constraints on precorrelator bandwidth, correlator spacing, differential group delay as applicable for the AEC of the equipment	Requirements met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
“	[092]	—	A, I	For equipment with E-L DLL discriminators, the discriminator (Δ) is based on an average of early minus late samples	Requirement met
“	[093]	—	A, I	Equipment with DD DLL discriminators meet the design constraints on precorrelator bandwidth, correlator spacings, differential group delay as applicable for the AEC	Requirements met
“	[304]	—	A, I	Equipment with DD DLL discriminators meet pre-correlation filter roll-off requirement	Requirement met
“	[396]	—	A, I	Equipment with DD DLL discriminators meet the pre-correlation filter stop band attenuation requirement	Requirement met
2.3.6.4.2 Correlation Peak Validation	[094]	—	A, I	Equipment acquires the main C/A code correlation peak	Requirement met
“	[270]	—	A, I	Equipment with DD DLL discriminators operate at the tracking point corresponding to the strongest peak	Requirement met
2.3.6.4.3 GPS Satellite Acquisition Time	[095]	(Note 1)	T	Equipment meets satellite acquisition time requirements of DO-229()	Requirements met
2.3.6.4.4 GPS Satellite Reacquisition Time	[096]	(Note 1)	T	Equipment meets satellite reacquisition time requirements of DO-229()	Requirements met
2.3.6.4.5 GPS Satellite Initial Acquisition Time	[406]	(Note 1)	T	Equipment meets satellite initial acquisition time requirements of DO-229() with expections as noted	Requirements met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
2.3.6.5 SBAS Signal Processing	[097]	(Note 1)	A, D, I, T	When using SBAS ranging sources, the equipment meets specified requirements from DO-229() with exceptions as noted	Requirements met
“	[305]	—	I	Equipment uses either E-L or DD DLL discriminators	Requirement met
“	[288]	—	A, I	For tracking SBAS satellites, the equipment meets the specified design constraints on precorrelator bandwidth, correlator spacing, differential group delay as applicable for the AEC	Requirements met
“	[272]	—	A, I	For tracking SBAS satellites, equipment with DD DLL discriminators meets the specified precorrelator filter requirement	Requirement met
2.3.6.6 Smoothing	[098]	—	A, D, I	Equipment performs carrier smoothing	Requirement met
“	[306]	—	A, D, I	Equipment steady-state CSC filter characteristics as specified	Requirement met
“	[307]	—	A, D, I	Equipment start-up CSC filter characteristics as specified	Requirement met
“	[308]	—	A, D, I	Equipment raw pseudorange input to the CSC is as specified	Requirement met
2.3.6.6.1 AEC D Smoothing	[319]	—	A, D, I	AEC D Equipment performs second set of carrier smoothing	Requirement met
“	[320]	—	A, D, I	AEC D second steady-state CSC filter characteristics as specified	Requirement met
“	[321]	—	A, D, I	AEC D second start-up CSC filter characteristics as specified	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.6.7 Measurement Quality Monitoring	[100]	—	A, D, I, T	Equipment performs measurement quality monitoring sufficient to satisfy the equipment integrity allocation	Requirement met
2.3.6.8.1 Accuracy, GPS Satellites	[101]	2.5.3.2	T	Equipment meets GPS accuracy requirement	The steady-state RMS_PR error statistic is less than the pass threshold
2.3.6.8.1.1	[322]	—	I	AEC C equipment accuracy specified as one of the accuracy designators A, or B.	Requirement Met
“	[323]	—	I	AEC D Equipment accuracy specified as AAD B.	Requirement Met
2.3.6.8.2 Accuracy, SBAS satellites	[102]	2.5.3.2	T	Equipment meets SBAS accuracy requirement	The steady-state RMS_PR error statistic is less than the pass threshold
“	[309]	—	A, T	Equipment tracking SBAS satellites must meet the relative (to GPS) tracking bias requirement	Requirement met
2.3.6.9 Integrity in the Presence of Interference	[103]	2.5.3.3	T	Equipment produces no misleading information in the presence of unintentional interference	Receiver error for PRN6 when declared valid is less than a specified value in the presence of CW interference offset from PRN6 carrier
2.3.6.10 Integrity in the Presence of Abnormal Dynamics	[104]	—	T	Equipment produces no misleading information when exposed to abnormal dynamics	Output errors do not exceed their corresponding protection levels

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
"	[105]	—	T	Equipment meets accuracy requirements when returned to normal dynamics	σ_{noise} determined by receiver, bounds actual error and meets accuracy requirement
"	[106]	—	T	Alerts shall function as specified when the equipment is exposed to abnormal dynamics	σ_{noise} determined by receiver, bounds actual error
2.3.6.11 Airborne Code Carrier Divergence Filerting	[324]	—	I	AEC D equipment includes specified CCD monitor	Requirement met
"	[325]	—	T	CCD filter operates at all times after take off and until the approach and landing operation is completed	Requirement met
2.3.7 Message Processing Function	[107]	—	D	Equipment is capable of processing Message Types 1, 2, and 4	Requirement met
"	[326]	—	D	AEC D equipment is capable of processing Message Type 11	Requirement met
"	[277]	—	D	Equipment uses the message length parameter so it can decode Type 2 messages whether they include additional blocks or not	Requirement met
2.3.7.1 VDB Message Validity Check	[108]	—	D	Equipment ignores messages for which the CRC check does not pass	Requirement met
2.3.7.2 VDB Message Block Identifier Check	[109]	—	D	Equipment ignores messages for which the message block identifier does not indicate "Normal LAAS"	Requirement met
2.3.7.3 VDB Message Authentication Protocols	[327]	—	A, D, I, T	AEC D equipment conforms to authentication protocols	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
“	[328]	—	D, T	Check the RPI first character to determine if authentication protocol must be followed	Requirement met
“	[329]	—	T	Exercise all authentication protocols	Verify that each protocol is handled properly.
“	[330]	—	D, T	If any authentication protocols fails, remove or flag deviations and LAAS differential PVT within specified time	Verify that removing or invalidating occurs within specified time.
“	[331]	—	T	Do not exercise any of the authentication protocols if RPI character is not in the designated set of characters for authentication	Verify that authentication protocol is not used.
2.3.7.4 Message Processing Requirements for Forward Capability	[402]	—	D, T	Equipment not adversely affected by any message types not supported	Requirement met
“	[403]	—	D, T	Equipment not adversely affected by additional data blocks in Message Type 2.	Requirement met
“	[404]	—	D, T	Equipment not adversely affected by specified data blocks in Message Type 4.	Requirement met
2.3.8.1.1 Ephemeris CRC Conditions	[117]	—	D	The PAN shall not use a ranging source in the position solution until it verifies the ephemeris CRC for that source	Requirement met
“	[273]	—	T	The PAN compares the calculated CRC with the broadcast CRC within the specified time of receiving a new broadcast IOD	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
"	[118]	—	D	The equipment ceases using any satellite for which the calculated and broadcast CRCs do not match	Requirement met
2.3.8.1.2 Reference Time Conditions	[120]	—	D	All satellites used in the position solution use corrections from the same ground station and with the same reference time	Requirement met
"	[121]	—	D	The most recently received set of corrections is applied	Requirement met
"	[122]	—	D	If the Type 1 message indicates that there are no corrections, then the equipment does not apply any corrections	Requirement met
2.3.8.1.3 Other Ranging Source Conditions	[123]	—	D	Differential corrections are only applied to a ranging source if all of the conditions of this paragraph are satisfied (a through f)	Requirement met
"	[136]	—	D	σ_{pr_gnd} for the ranging source is not set to "1111 1111"	Requirement met
"	[280]	—	D	The measurement type of the corrections matches the airborne measurement being corrected	Requirement met
"	[137]	—	D	For GPS, the IOD of the correction matches the IODE and the 8 LSBs of the IODC in the satellite ephemeris	Requirement met
"	[138]	—	D	The elapsed time since the receipt of the last Type I message is < the specified interval	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
“	[139]	—	D	The difference between the current time and the reference time of the correction is < the specified interval	Requirement met
“	[282]	—	D	The difference between the current time and the time of applicability for the ephemeris decorrelation parameter (p) associated with that ranging source < the specified interval	Requirement met
2.3.8.1.3.1 Ranging Source Conditions for AEC D Equipment	[332]	—	D	Differential corrections are only applied to a ranging source if all of the conditions of this paragraph are satisfied for GAST D	Requirement met
“	[333]	—	D	$\sigma_{pr\_gnd\_30}$ for the ranging source is not set to “1111 1111”	Requirement met
“	[334]	—	D	$\sigma_{pr\_gnd\_100}$ for the ranging source is not set to “1111 1111”	Requirement met
“	[335]	—	D	The elapsed time since the receipt of the last Type 1 message is < the specified interval when the computed position is in the specified location	Requirement met
“	[336]	—	D	The elapsed time since the receipt of the last Type 11 message is < the specified interval when the computed position is in the specified location	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
“	[337]	—	D	The difference between the current time and the reference time of the correction is < the specified interval when the computed position is in the specified location	Requirement met
“	[393]	—	D	The elapsed time since the receipt of the last Type 1 message is < the specified interval when the computed position is in the specified location	Requirement met
“	[394]	—	D	The elapsed time since the receipt of the last Type 11 message is < the specified interval when the computed position is in the specified location	Requirement met
“	[395]	—	D	The difference between the current time and the reference time of the correction is < the specified interval when the computed position is in the specified location	Requirement met
“	[338]	—	D	The difference between the current time and the time of applicability for the ephemeris decorrelation parameter (p) associated with that ranging source < the specified interval	Requirement met
2.3.8.2.1 Application of Differential Corrections for 100 Second Smoothed Pseudoranges	[124]	—	D	Equipment computes corrected 100-second smoothed pseudoranges as specified	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.8.2.2 Application of Differential Corrections for 30 Second Smoothed Pseudoranges	[339]	—	D	Equipment computes corrected 30-second smoothed pseudoranges as specified	Requirement met
2.3.8.3 Tropospheric Correction	[125]	—	D	Tropospheric correction is computed as specified	Requirement met
2.3.9 LAAS Differential Positioning Requirements	[126]	—	A, D, I	The PAN computes three-dimensional position using a linearized, weighted least squares algorithm and differentially corrected pseudoranges	Requirement met
“	[274]	—	D	The position solution uses message data from the same ground station	Requirement met
“	[127]	—	D	The PAN does not apply differential corrections when corrections are available from fewer than the specified number of satellites	Requirement met
“	[317]	—	A, D, I, T	When supporting GAST C or the positioning service, PAN uses valid measurements from all satellites for which differential corrections are received, up to at least 10 satellites	Requirement met
“	[128]	—	T	The position solution reflects the message data within the specified interval of the output of the last bit of a valid message from the VDB function	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.9.1 Differential Position Solution – One Acceptable Means	[129]	—	A, D, I, T	3D position error due to discontinuities between sets of corrections is < the specified magnitude	Requirement met
2.3.9.2.1 Differential Position Solution for the GBAS Positioning Service	[340]	—	D	Position solution for PVT output is based on 100 second smoothed pseudoranges with MT 1 corrections applied	Requirement met
"	[341]	—	D	Position solution projection matrix, S, used for PVT output based on specified parameters	Requirement met
2.3.9.2.2 Differential Position Solution for Approach Service GAST C	[342]	—	D	Position solution used to generate deviations for GAST C based on 100 second smoothed pseudoranges with MT 1 corrections applied	Requirement met
"	[343]	—	D	Position solution projection matrix, S, for GAST C based on specified parameters	Requirement met
2.3.9.2.3 Differential Position Solution for Approach Service GAST D	[344]	—	D	One of two position solutions for GAST D based on 100 second smoothed pseudoranges with MT 1 corrections applied	Requirement met
"	[345]	—	D	Second of two position solutions for GAST D used to generate deviations based on specified parameters	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
“	[346]	—	D	Position solution projection matrix, S, for GAST D based on specified parameters	Requirement met
2.3.9.3 Dual Solution Ionospheric Gradient Monitoring	[347]	—	D	Compute difference between two position solutions while supporting GAST D	Requirement met
“	[348]	—	D	Respond as specified if vertical difference between GAST D position solutions is exceeded.	Requirement met
2.3.9.4 Satellite Geometry Screening	[349]	—	D	Perform satellite geometry screening as specified	Requirement met
2.3.9.5 Differential Correction Magnitude Check	[350]	—	D	AEC D performs differential correction magnitude check	Requirement met
“	[351]	—	D	Compute magnitude of projection of differential corrections in the horizontal position as specified	Requirement met
“	[352]	—	D	Respond to magnitude check as specified	Requirement met
2.3.9.6 Fault Detection	[353]	—	D	Perform RAIM FD as specified for GAST D	Requirement met
“	[354]	—	D	Perform RAIM FD at specified rate and at specified times	Requirement met
“	[355]	—	D	Respond to fault detection as specified	Requirement met
“	[356]	—	A, D	Probability of false alert as specified	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
2.3.9.6.1 Fault Detection for Satellite Addition	[357]	—	D	Perform fault detection for addition of a satellite to GAST D precision approach position solution at least once after CCD monitor has converged.	Requirement met
"	[358]	—	A, D, I, T	Form test statistic and compare to threshold to provide specified probability of false alert	Requirement met
"	[397]	—	A, D, I, T	Compute VPL_{FD} and LPL_{FD} as specified	Requirement met
"	[398]	—	A, D, I, T	Compute VPL_{FD} and LPL_{FD} based on specified hypothesis	Requirement met
"	[359]	—	D	Do not use a new satellite until specified conditions are met	Requirement met
2.3.10 PVT Outputs	[278]	—	D	The PAN verifies that the ground station supports differentially corrected positioning service and that the distance between the aircraft and the GBAS reference point is less than the maximum GBAS usable distance if broadcast in the Type 2 message before outputting corrected position	Requirement met
"	[130]	—	D, T	Differentially corrected PVT outputs shall be of the specified form, and at the specified output rate	Requirement met
2.3.10.2 Horizontal Protection Level, Ephemeris Error Position Bounds, and Figures of Merit	[180]	—	A, D, I	The equipment computes position protection levels for each corrected PVT output and the figures of merit (HFOM & VFOM)	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
"	[131]	—	A, D, I	The equipment outputs position protection level for each corrected PVT output	Requirement met
"	[132]	—	A, D, I	The equipment indicates if position protection level cannot be calculated	Requirement met
2.3.10.3 Figures of Merit	[133]	—	A, D, I	When providing corrected PVT outputs, the equipment outputs position figures of merit calculated as specified and at the specified rate	Requirement met
"	[134]	—	A, D, I	The equipment indicates if figures of merit cannot be calculated	Requirement met
"	[360]	—	A, D, I	If providing Velocity Figure of Merit outputs, the equipment outputs velocity figures of merit calculated as specified and at the specified rate	Requirement met
2.3.10.4 PVT Output Latency	[151]	—	T	The interval between the time of applicability of the corrected PVT output and the time of the measurement is less than specified	Requirement met
"	[135]	—	T	The interval between the time of applicability of the corrected PVT data and the time of the data output is less than specified	Requirement met
2.3.10.5 Velocity Accuracy	[361]	—	A, D, I	Horizontal velocity accuracy meets specification	Requirement met
"	[362]	—	A, D, I	Vertical velocity accuracy meets specification	Requirement met
"	[363]	—	A, D, I	Velocity accuracy requirements met under minimum signal conditions	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.11.1.1 FAS Data Block Selection and Confirmation	[110]	—	D	The PAN selects from the Type 4 message, the FAS data corresponding to the selected approach	Requirement met
“	[111]	—	D	The PAN validates the CRC for the selected FAS data and only uses it if the CRC check passes	Requirement met
“	[112]	—	D	The PAN outputs the Reference Path Identifier of the validated FAS data	Requirement met
2.3.11.1.2 GBAS ID Selection	[113]	—	D	For determining the precision approach guidance outputs, the PAN only uses messages for which the GBAS ID matches the GBAS ID in the header of the selected FAS data block	Requirement met
2.3.11.1.3.2	[364]	—	D	Selected Approach Service Type not reflected until specified conditions are met	Requirement met
“	[365]	—	D	Select Approach Service Type according to requirements	Requirement met
“	[399]	—	D	Set selected approach service type according to requirements	Requirement met
“	[400]	—	D, I	Apply functional requirements as specified	Requirement met
“	[401]	—	D	Set selected approach service type according to requirements	Requirement met
2.3.11.1.3.3 Approach Service Type Output	[366]	—	D	Output selected and active Approach Service Type.	Requirement met
“	[367]	—	D	Output reflects change in active Approach Service Type within specified time	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.11.3 Approach Status Verification	[283]	—	D	The equipment evaluates the FAS vertical and lateral alert limit/approach status fields under the specified conditions	Requirement met
“	[284]	—	D	The equipment stops checking the FAS vertical and lateral alert limit/approach status fields under the specified conditions	Requirement met
“	[285]	—	T	When the FAS vertical and lateral alert limit/approach status fields take on certain values, the equipment sets deviations invalid within a specified time	Requirement met
2.3.11.4 Ground Continuity Integrity Designator (GCID) Conditions	[114]	—	D	The PAN does not output valid deviations until it verifies that the GCID has an acceptable value	Requirement met
“	[115]	—	T	When outside the PAR, the PAN continually verifies the GCID and sets deviations invalid within the specified time after receiving an invalid GCID	Requirement met
“	[116]	—	D	When inside the PAR, the PAN ignores any changes to the GCID	Requirement met
2.3.11.5.1 Deviations	[141]	—	A, D, I	The equipment outputs lateral and vertical proportional deviations	Requirement met
“	[140]	—	T	The PAN outputs precision approach guidance within the specified time after the specified conditions are met	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
“	[368]	—	T	The PAN outputs precision approach guidance within the specified time after the specified conditions are met	Requirement met
“	[142]	—	T	If provided, analog deviation outputs have the specified characteristics	Requirement met
2.3.11.5.1.1.1. Proportional Lateral Deviation	[145]	—	D	Sign convention of lateral deviations is as defined	Requirement met
“	[146]	—	A, D, I	Proportional lateral deviation is as defined in following subparagraphs (next three rows)	Requirement met
“	[148]	—	A, D, I	Deviation is angular over the interval defined	Requirement met
“	[149]	—	A, D, I	Deviation is angular or linear over the interval defined	Requirement met
“	[150]	—	A, D, I	Deviation is linear over the interval defined	Requirement met
“	[286]	—	A, I, T	The equipment provides lateral deviations to at least twice the full-scale deflection	Requirement met
“	[152]	—	A, I, T	For deviations greater than the maximum lateral deviation output, the equipment provides the maximum output value	Requirement met
2.3.11.5.1.1.2 Rectilinear Lateral Deviation	[153]	—	D	If provided, rectilinear deviation indicates distance of the GRP from the reference plane	Requirement met
2.3.11.5.1.2 Vertical Deviations for the Approach Segment	[154]	—	D	Vertical deviations are flagged under the conditions specified	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.11.5.1.2.1 Proportional Vertical Deviation	[155]	—	A, D, I	Proportional vertical deviation is as defined in following subparagraphs (next two rows)	Requirement met
"	[157]	—	A, D, I	Deviation is angular over the interval defined	Requirement met
"	[158]	—	A, D, I	Deviation is angular or linear over the interval defined	Requirement met
"	[159]	—	D	Sign convention of vertical deviations is as defined	Requirement met
"	[160]	—	A, I, T	The equipment provides vertical deviations to at least twice the full-scale deflection	Requirement met
"	[161]	—	A, I, T	For deviations greater than the maximum vertical deviation output, the equipment provides the maximum output value	Requirement met
2.3.11.5.1.2.2 Rectilinear Vertical Deviation	[162]	—	D	If provided, rectilinear vertical deviation indicates distance of the GRP from the reference surface	Requirement met
2.3.11.5.1.3 Deviation Output Rate and Latency	[143]	—	A, I, T	Deviations are computed and output from dynamically independent position updates at the rate specified	Requirement met
"	[144]	—	T	Deviation outputs meet the latency requirements specified	Requirement met
2.3.11.5.1.4 Missed Approach Guidance	[163]	—	D	If missed approach guidance is provided, the PAN sequences to outputting linear lateral deviations with the sensitivity specified	Requirement met
"	[164]	—	D	Vertical deviations are set invalid on the missed approach segment	Requirement met

Requirement Paragraph	**Desig-nator**	**Test Paragraph**	**Test Method**	**Requirement Summary**	**Pass/Fail Criteria**
“	[165]	—	D, I	The PAN sequences to missed approach guidance based on an external command	Requirement met
“	[166]	—	D	The equipment automatically sequences to missed approach guidance when all specified conditions are satisfied	Requirement met
2.3.11.5.2.1 Loss of Approach Guidance	[167]	—	T	The PAN indicates when the system is no longer adequate to execute precision approach	Requirement met
“	[168]	—	T	Lateral and vertical deviations are set invalid within a specified time of the onset of any of the listed conditions	Requirement met
2.3.11.5.2.1.1 Loss of Approach Guidance – GAST C	[169]	—	T	Lateral and vertical deviations are set invalid within a specified time of the onset of any of the listed conditions	Requirement met
“	[170]	—	T	Vertical deviations are set invalid within a specified time after the vertical protection level or vertical ephemeris error position bound exceeds the vertical alert limit	Requirement met
2.3.11.5.2.1.2 Loss of Approach Guidance – GAST D	[369]	—	T	Active Approach Service Type is invalid within a specified time of the onset of any of the listed conditions	Requirement met
“	[370]	—	D	When active Approach Service Type is invalid react according to specifications	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.11.5.2.1.1.1 Lateral Alert Limits	[171]	—	D	The lateral alert limit is determined as specified when computed position is inside the PAR and bearing to the LTP is < ±90 deg	Requirement met
"	[275]	—	D	The lateral alert limit is determined as specified when computed position is inside the PAR and bearing to the LTP is > ±90 deg	Requirement met
"	[172]	—	D	Lateral alert limit is determined as specified when computed position is outside the PAR and the approach is selected	Requirement met
2.3.11.5.2.1.1.2 Vertical Alert Limits	[173]	—	D	The vertical alert limit is determined as specified when computed position is inside the PAR	Requirement met
"	[174]	—	D	The vertical alert limit is determined as specified when computed position is outside the PAR and the approach is selected	Requirement met
2.3.11.5.2.1.2 Lateral and Vertical Protection Levels	[179]	—	D	Protection levels are calculated as specified for each Type I message used in the navigation solution	Requirement met
2.3.11.5.2.1.3 Vertical & Lateral Ephemeris Error Position Bounds	[287]	—	D	Ephemeris error position bounds are calculated as specified for each Type I message used in the navigation solution	Requirement met
2.3.11.5.2.2 Bias Approach Monitor (BAM)	[181]	—	A, D, I	The BAM evaluations are performed as specified	Requirement met
"	[182]	—	D	If either BAM evaluation fails, the vertical and lateral deviations are set invalid	Requirement met

Requirement Paragraph	Desig-nator	Test Paragraph	Test Method	Requirement Summary	Pass/Fail Criteria
2.3.11.5.2.3	[371]	—	D	Perform Reference Receiver Fault Monitor and respond as specified	Requirement met
2.3.11.5.2.4	[372]	—	D	Use specified parameters in protection levels, ephemeris protection bounds and BAM evaluations as a function of Service Type	Requirement met
2.3.11.5.3 Distance to Threshold	[183]	—	A, D, I	Distance to threshold is calculated from independent position updates	Requirement met
2.3.11.5.3.1 Distance to Threshold Output	[184]	—	T	The PAN outputs Distance to Threshold at the minimum specified rate whenever lateral deviations are output	Requirement met
2.3.11.5.3.2 Distance to Threshold Output Latency	[185]	—	T	The Distance to Threshold output meets the latency requirement	Requirement met
2.3.12.1 Model of Airborne Pseudorange Performance	[175]	—	D	σ_{pr_air} is computed as specified	Requirement met
"	[176]	—	A, D, I	The value of $\sigma^2_{divg}[i]$ is set as specified	Requirement met
"	[177]	2.5.3.2	T	The value of $\sigma_{noise}[i]$ bounds the actual receiver error as specified	The RMS_PR error statistic is less than the pass threshold
"	[292]	2.5.3.2	T	The steady-state value of $\sigma_{noise}[i]$ is less than specified	The average steady-state $\sigma_{noise}[i]$ is less than specified
2.3.12.2 Model of Tropospheric Residual Uncertainty	[178]	—	D	σ_{tropo} is computed as specified	Requirement met
2.3.12.3 Model of Ionospheric Residual Uncertainty	[279]	—	D	σ_{iono} is computed as specified	Requirement met

Note 1: Unless otherwise specified, for requirements that reference RTCA/DO-229(), refer to RTCA/DO-229() for acceptable test procedures.

2.5.2 VDB Receiver Subsystem Test Procedures

2.5.2.1 Definition of VDB Test Terms and Conditions

2.5.2.1.1 Standard Test Signals

Standard VDB Test Signal – An RF carrier, differentially encoded 8 phase shift keyed modulation at a rate of 10,500 symbols per second (3-bits/symbol). The time division multiple access technique shall *[LAAS-206]* be a synchronized fixed frame structure. The baseline VDB configuration is derived from RTCA/DO-245() and RTCA/DO-246(), and the FAA LAAS Ground Facility Specification. The Standard VDB Test Signal may include both a Message Generator function and the VDB Signal Generator.

Desired VDB Signal Level – When testing in conditions associated with the interference requirements defined in Sections 2.2.7, 2.2.8 and 2.2.9, the minimum power of the desired signal applied to the VDB receiver subsystem will be S_{min} and the maximum signal power applied will be S_{max}. The tests of Sections 2.2.5 and 2.2.6 do not include interference and need to be performed with the minimum signal power reduced by 3 dB (i.e., to S_{min} – 3 dB) to ensure that the receiver meets the requirements of Sections 2.2.7, 2.2.8 and 2.2.9 in the presence of each of these specific cases of interference individually applied.

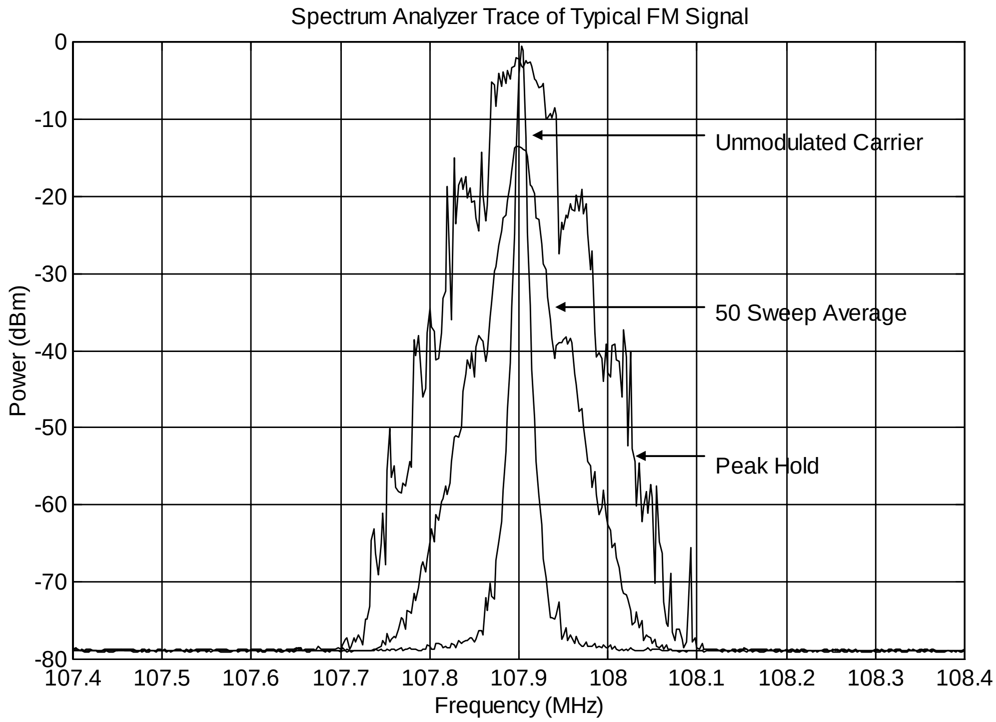
Note: It is acceptable to make frequency measurements when the Standard VDB Test Signal is operating with an unmodulated carrier.

Note: S_{min} and S_{max} are defined in Section 2.2.5.

Standard VOR Test Signal – An RF carrier, amplitude modulated simultaneously (a) 30 ±1% by a "reference phase signal," composed of a 9,960 Hz subcarrier, which is, in turn, frequency modulated at a deviation ratio of 16 by a 30 ±1% Hz signal, and (b) 30 ±1% by a 30 ±1% Hz "variable phase signal" which can be varied in phase with respect to the 30 Hz FM of the reference phase signal.

Standard ILS Localizer Test Signal – An RF carrier, amplitude modulated simultaneously (a) 20 ±1% by a 90 Hz ±0.3% sine wave and (b) 20 ±1% by a 150 Hz ±0.3% sine wave. The difference in depth of modulation (ddm) shall *[LAAS-207]* be less than 0.002.

Standard FM Broadcast Signal – An RF carrier, frequency modulated with CCIR colored noise or pink noise with a peak frequency deviation of ±75 kHz. A typical spectrum analyzer trace for the simulated FM broadcast is shown in Figure 2-9.



<u>Figure 2-9</u> **Typical Simulated FM Broadcast Spectrum**

2.5.2.1.2 Test Message Format

The desired and undesired VDB signal sources shall *[LAAS-208]* generate time varying full-length (222 bytes) application data messages that change from slot to slot within a given frame and also vary from frame to frame. In addition, a means must be provided to account for the number of messages sent by the desired VDB Message/Signal Generator. This is required to insure an accurate count of any messages lost by the VDB receiver subsystem.

<u>Notes</u>:

1) *In order to decrease test times, the desired VDB Message/Signal Generator and the VDB receiver subsystem are allowed to operate using 8 slots per frame, for a total of 16 messages per second.*

2) *The test message format is intended to permit the rapid characterization of the VDB receiver subsystem and does not specifically follow the LAAS messages specified in RTCA/DO-245() and RTCA/DO-246().*

2.5.2.1.3 Statistical Sample Size and Pass/Fail Criteria

For each and every test condition that involves determining the message failure rate of the VDB receiver subsystem, the VDB Message/Signal Generator shall *[LAAS-209]* transmit 10,000 application data messages in accordance with Section 2.5.2.1.2. The pass/fail criteria for a given test shall *[LAAS-210]* be determined using the following criteria:

a) If fifteen (15) or less messages are failed (lost by the VDB receiver subsystem or do not pass CRC), then the VDB receiver subsystem passes the current test. This is equal to a measured MFR of 0.15%.

b) If sixteen (16) or more messages are failed (lost by the VDB receiver subsystem or do not pass CRC), then the VDB receiver subsystem fails the current test. This is equal to a measured MFR of 0.16%.

Note: *The rationale for these criteria is defined in Appendix H.*

2.5.2.1.4 Standard Output

The output of the VDB receiver subsystem (and data collection computer) shall *[LAAS-211]* provide a means for computing the MFR, correctly accounting for messages lost by the VDB receiver subsystem and those messages that do not pass CRC.

2.5.2.2 Detailed Test Procedures

The following test procedures are considered satisfactory in determining required performance. Although specific test procedures are cited, it is recognized that other methods may be utilized. These alternate procedures (and test configurations) may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of any alternative test procedures.

2.5.2.2.1 General Requirements

No specific test procedures are cited for the General Requirements, Design Assurance, Software, or Hardware sections.

2.5.2.2.2 Tuning

2.5.2.2.2.1 Frequency Range

Compliance to this requirement can be demonstrated by successfully passing the tests specified in Section 2.5.2.2.5.

2.5.2.2.2.2 Frequency Selection

Compliance to this requirement can be demonstrated by successfully passing the tests specified in Section 2.5.2.2.5.

Note: *When a frequency is referenced in the tests in this section, either the VDB frequency or the associated LAAS channel number is employed per Section 2.2.2.2.*

2.5.2.2.2.3 Response Time

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Oscilloscope, 500 MHz (Tektronix TDS 654C, or equivalent)

e) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

f) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

g) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

h) VDB Receiver

i) Data Collection Computer

j) Tuning Controller

Note: *The tuning controller is shown explicitly in this test configuration because of its relevance to the requirement under consideration. A tuning controller is not shown in all other test configuration. However, it is assumed that a means of tuning the VDB receiver is provided in each case.*

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-10.

2) Adjust the signal level at the VDB receiver input to be S_{min} + 30 dB.

3) Tune the VDB Receiver to 108.000 MHz.

4) Set the VDB Message/Signal Generator to transmit messages at 113.000 MHz.

5) Tune the VDB Receiver to 113.000 MHz and record the difference in time between the output of the first valid message block and the receipt of the last bit of the 113.000 MHz tuning command.

6) The test is successful if this time difference is within that specified in Section 2.2.2.3.

Notes:

1) A signal power level of S_{min} + 30 dB was chosen in order to give a good signal-to-noise ratio with negligible message failures.

2) Since this requirement does not deal specifically with MFR, the number of messages used to determine the response time is not critical. However, it is recommended that at least 10 measurements be documented to ensure accuracy.

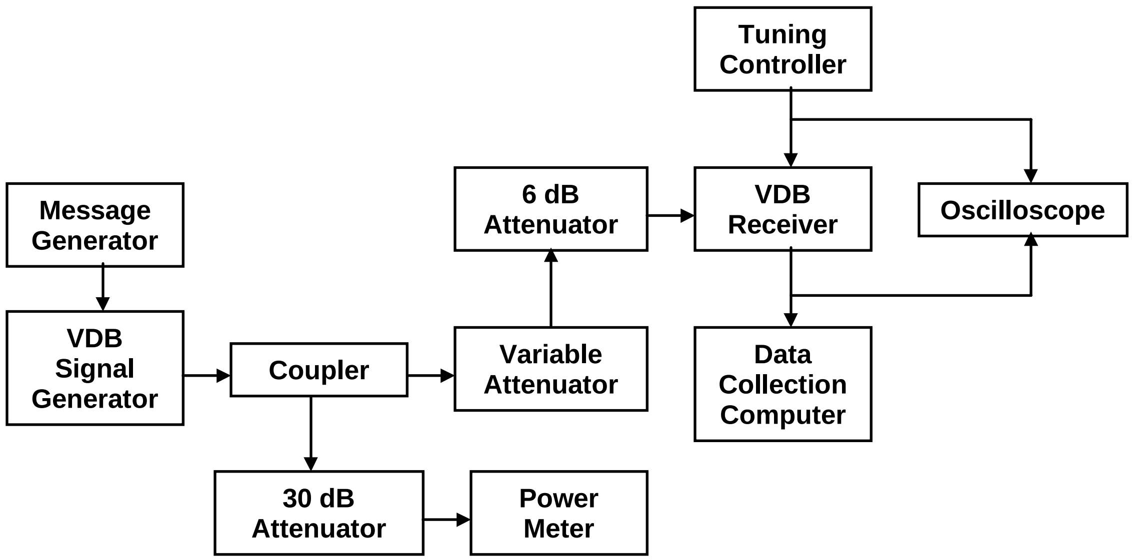


Figure 2-10 **Response Time Test Equipment Connection**

2.5.2.2.3 Data Latency

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Oscilloscope, 500 MHz (Tektronix TDS 654C, or equivalent)

e) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)) and

f) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

h) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

i) VDB Receiver

j) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-11.

2) Adjust the desired signal power at the VDB receiver input to be S_{min} + 30 dB.

3) Tune the VDB Receiver and VDB Message/Signal Generator to 113.000 MHz.

4) Record the difference in time between the output of the last bit of the first valid message block and the receipt of the last bit of the corresponding RF message.

5) The test is successful if this time difference is within that specified in Section 2.2.3.

Note: *Since this requirement does not deal specifically with MFR, the number of messages used to determine the response time is not critical. However, it is recommended that at least 10 measurements be documented to ensure accuracy.*

Note: *A signal power level of S_{min} + 30 dB was chosen in order to give a good signal-to-noise ratio with negligible message failures.*

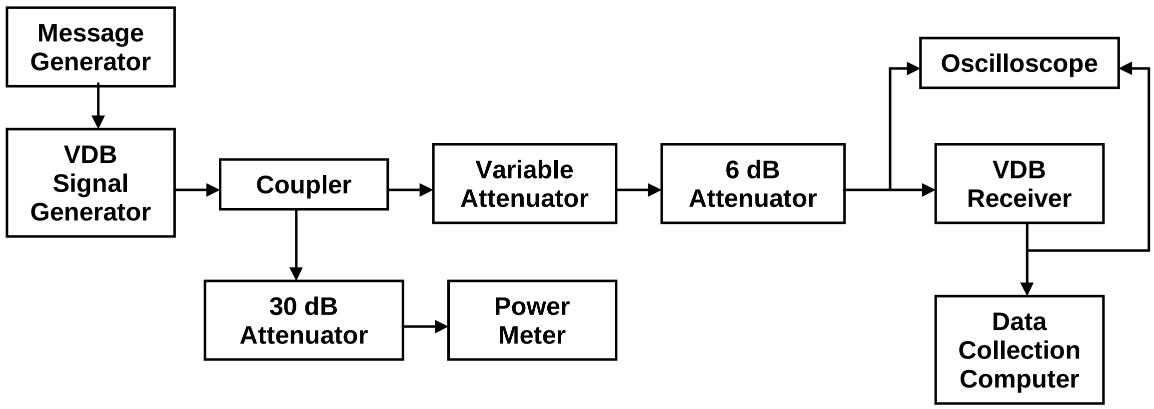


Figure 2-11 Data Latency Test Equipment Connection

2.5.2.2.4 Data Format Decoding

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and

e) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

f) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

g) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

h) VDB Receiver

i) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-12.

2) Adjust the desired signal power at the VDB receiver input to be S_{min} + 30 dB.

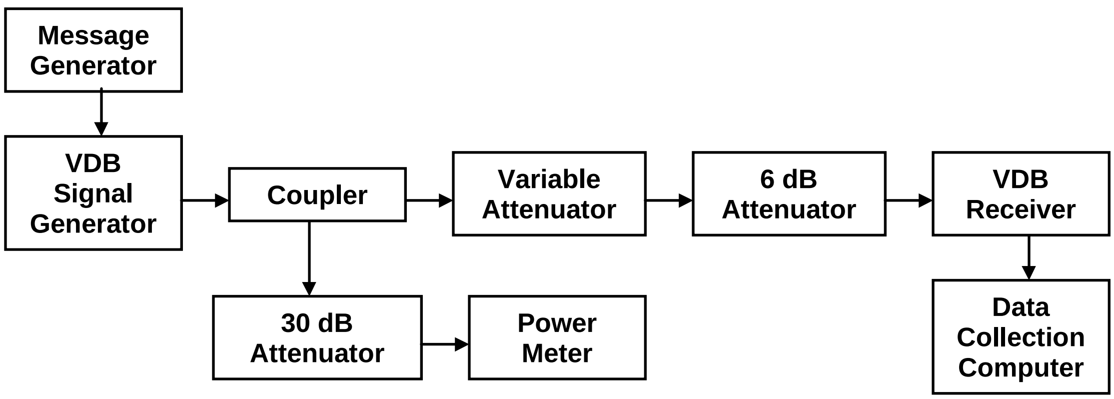
3) Tune the VDB Receiver and VDB Message/Signal Generator to 113.000 MHz.

4) Set the VDB Message/Signal Generator to generate the message specified in RTCA/DO-246() Appendix B, Entitled "Type 4 Message Formatting Example".

5) Using the VDB Receiver and Data Collection Computer, record the Application Data Output message.

6) Perform a bit-by-bit comparison of the received application data with that transmitted. Any discrepancy indicates a failure of this test.

<u>Note</u>: *A signal power level of S_{min} + 30 dB was chosen in order to give a good signal-to-noise ratio with negligible message failures.*



<u>Figure 2-12</u> Data Format Decoding Test Equipment Connection

2.5.2.2.5 Message Failure Rate

2.5.2.2.5.1 Sensitivity and Dynamic Range

Compliance to this requirement can be demonstrated by the successful completion of all requirements requiring an MFR determination.

<u>Equipment List</u>

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

e) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

f) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

g) VDB Receiver

h) Data Collection Computer

<u>Detailed Test Procedure</u>

1) Connect the equipment as shown in <u>Figure 2-13</u>.

2) Adjust the desired signal power at the VDB receiver input to be S_{min} – 3 dB.

3) Tune the VDB Message/Signal Generator and VDB Receiver to 108.000 MHz.

4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the received power and test frequency combinations listed in Table 2-23.

Table 2-23 Test Conditions for Sensitivity and Dynamic Range Tests

Received Power	Test Frequencies
S_{min} – 3 dB	108.000, 113.000 and 117.975 MHz
S_{max}	108.000, 113.000, and 117.975 MHz

The pass/fail outcome of all six received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

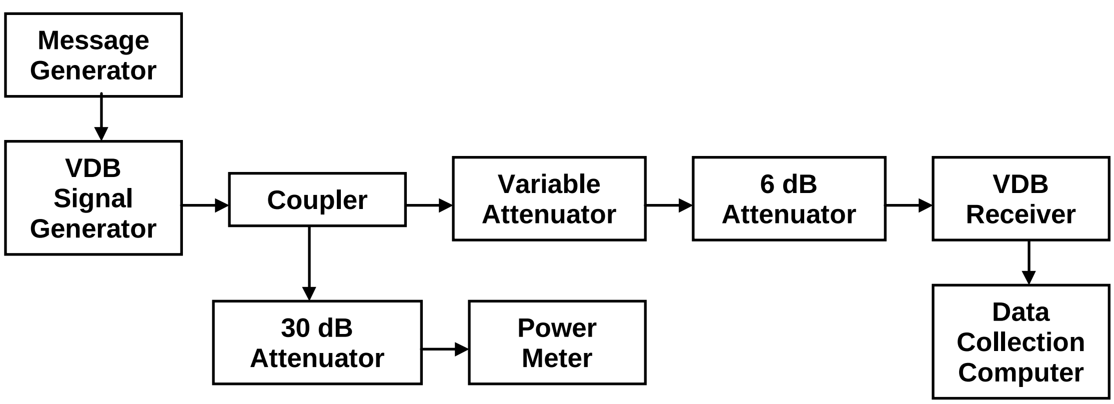


Figure 2-13 Sensitivity and Dynamic Range in an AWGN Channel Test Equipment Connection

2.5.2.2.5.2 Frame-to-Frame Variations for a Given Slot

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)

e) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

f) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

g) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

h) VDB Receiver

i) Data Collection Computer

j) Timing Circuit

k) Single Pole, Single Throw RF Switch (Mini-Circuits ZFSWHA-1-20, or equivalent)

l) Single Pole, Double Throw RF Switch (Mini-Circuits ZFSW-2-46, or equivalent)

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-16.

2) Adjust the timing circuit, RF switch, and attenuators such that the signal level at the VDB receiver input varies according to the diagram given in either Figure 2-14 or Figure 2-15 depending on the condition being tested.

3) Verify that the synchronization of the VDB Signal Generators is within 95.2 microseconds.

Note: *The value of 95.2 microseconds corresponds to the slot synchronization time given in DO-246() for VDB bursts in a time slot.*

4) Tune the VDB Message/Signal Generator and VDB Receiver to 108.000 MHz.

5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

6) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

7) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the power conditions and test frequency combinations listed in Table 2-24.

Table 2-24 Test Conditions for Frame-to-Frame Variation Tests

Figure	Power Range	Test Frequencies
Figure 2-14	$(S_{min} - 3)$to $(S_{min} - 3 + \Delta S_{max})$	108.000, 113.000, and 117.975 MHz
Figure 2-15	$(S_{max} - \Delta S_{max})$ to S_{max}	108.000, 113.000, and 117.975 MHz

The pass/fail outcome of all six received power differentials and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

Note: *This test is designed to verify the performance of the AGC of the VDB receiver subsystem over a 10-second interval. This scenario can be encountered if the LAAS ground facility transmits Type 4 messages at the minimum specified rate.*

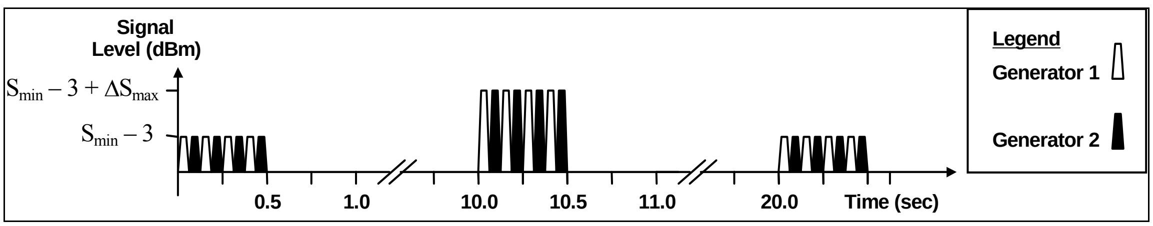


Figure 2-14 Frame-to-Frame Timing Diagram 1

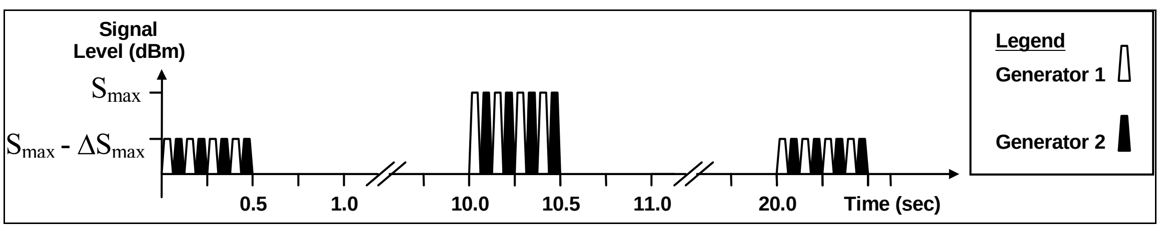


Figure 2-15 Frame-to-Frame Timing Diagram 2

2.5.2.2.5.3 Slot-to-Slot Variations Within a Given Frame

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)

e) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

f) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

g) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

h) VDB Receiver

i) Data Collection Computer

j) Timing Circuit

k) Single Pole, Single Throw RF Switch (Mini-Circuits ZFSWHA-1-20, or equivalent)

l) Single Pole, Double Throw RF Switch (Mini-Circuits ZFSW-2-46, or equivalent)

Detailed Test Procedures

1) Connect the equipment as shown in Figure 2-16.

2) Adjust the timing circuit, RF switch, and attenuators such that the signal level at the VDB receiver input varies according to the diagram given in Figure 2-17.

3) Verify that the synchronization of the VDB Signal Generators is within 95.2 microseconds.

Note: *The value of 95.2 microseconds corresponds to the slot synchronization time given in DO-246() for VDB bursts in a time slot.*

4) Tune the VDB Message/Signal Generator and VDB Receiver to 108.000 MHz.

5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

6) Using the VDB Receiver and Data Collection Computer, determine the MFR for all messages at both (S_{min} – 3 dB) and S_{max} signal levels using the methodology specified in Section 2.5.2.1.3.

7) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the test frequencies listed in Table 2-25.

Table 2-25 Test Frequencies for Slot-to-Slot Variation Tests

Test Frequencies
108.000, 113.000, and 117.975 MHz

The pass/fail outcome of the three test frequencies must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

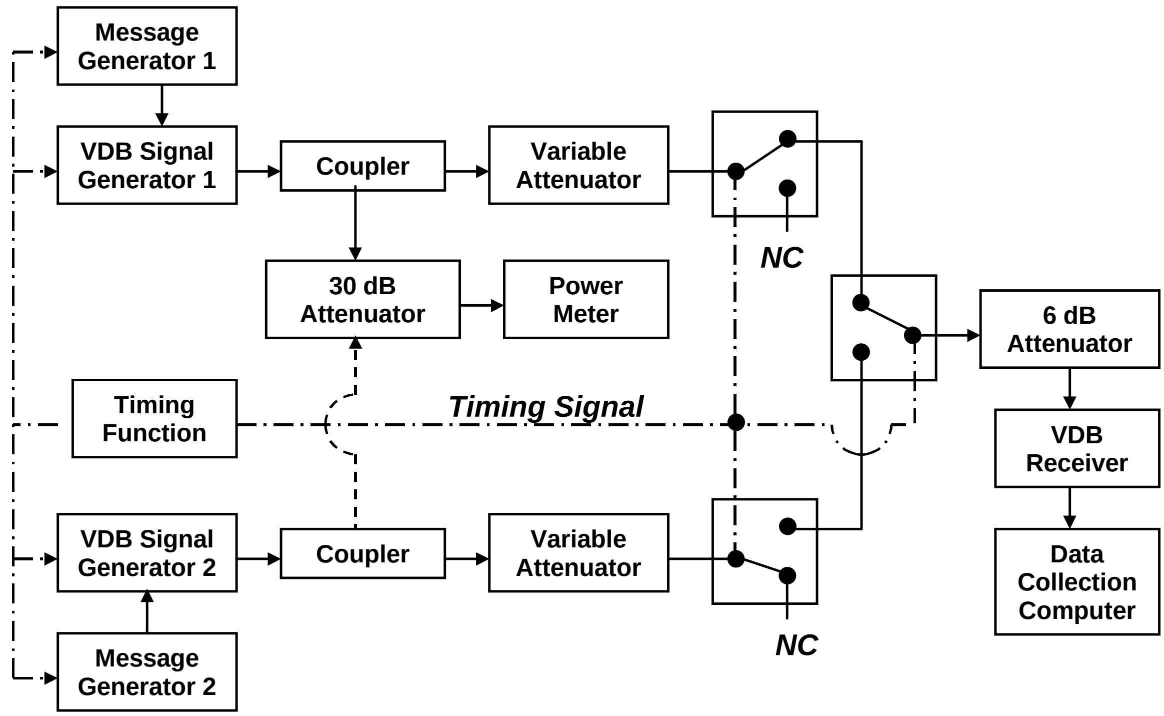


Figure 2-16 **Slot-to-Slot (and Frame-to-Frame) Variation Test Equipment Connection**

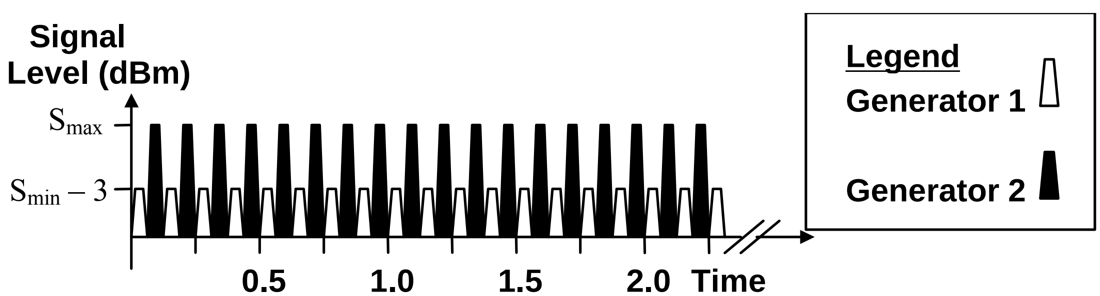


Figure 2-17 **Slot-to-Slot Timing Diagram**

2.5.2.2.5.4 Training Sequence and Message Failure Rate Test

Note: *The Synchronization and Ambiguity Resolution segment of the training sequence may, by chance, occur in the application data portion of a transmitted VDB message. This test ensures that the receiver meets the message failure rate in cases where this occurs.*

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

e) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

f) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

g) VDB Receiver

h) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-13.

2) Adjust the desired signal power at the VDB receiver input to 0.5 (S_{min} + S_{max}).

3) Tune the VDB Message/Signal Generator and VDB Receiver to 113.000 MHz.

4) Following the guidelines in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the non-time-varying full-length (222 bytes) application data message shown in Table 2-26, transmitting the data from left-to-right and top-to-bottom. Repeat that message to produce the number of test messages specified in Section 2.5.2.1.3.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Table 2-26 Embedded Synchronization and Ambiguity Resolution Sequence Test Message

Note: This table is preconditioned to appear as 37 Synchronization and Ambiguity Resolution Sequences after being scrambled for transmission.

01000011	11111111	01110110	00011010	00100100	01111000
11011100	00111001	01011100	11101101	10111101	00110010
11111111	00100001	00100111	00110010	11100111	11100110
00100110	00010000	00000100	10001110	10011101	10110110
10000001	00101110	01110000	11011001	11010010	10000010
01101010	10011111	00010101	01100101	01011111	00101100
01111000	11110111	00101101	11111010	11111110	11111001
11111010	00111010	11010100	11101000	01011101	00111111
10000000	11001101	10001101	10100011	01111110	00100100

00000100 11101000 01111101 11010001 11000001 01100010
01010000 00011111 01001100 10011010 01111101 10000111
11111110 10010010 11011010 10001000 01001010 01000000
01001011 10011000 10010110 10010000 10100101 10011110
11011110 10110001 01011010 11110010 01001010 11100111
10110101 11101101 11000001 11011100 01101110 10001111
11000101 01110010 10000000 00001000 10010011 10111110
10010110 11001110 01000101 10100110 01100001 11010111
11010001 10101101 01001110 11011101 10000101 01110010
10100000 00100001 11110011 00110011 11010111 11100101
10011001 11101010 01010001 11010110 01010001 01101000
01101111 11111000 11100110 00010000 00011011 10011111
01110110 10110011 00111010 11110101 00110101 00010011
00011111 01011100 01011000 01100001 10110011 00100010
11101000 11100001 00010010 00110010 10101011 11100110
11001001 11101110 10010001 11011000 10101110 10000001
00111010 10011011 11010101 01101011 10100000 11000101
00101101 10010100 00011110 10000001 01000101 10100011
10100001 00011101 11110000 10011100 00101101 10001111
00111110 10001100 00100101 01011110 11100000 10001001
11010010 10000101 01001010 10111101 10001010 00001101
01001011 01110100 10010111 11111111 01011001 00001011
10001111 01111101 10011000 00011100 10110011 10001110
11101001 01110001 00010000 00001101 01010011 10110011
10010110 11011101 10111010 01100011 00110100 11011011
00011101 10111100 01011110 11100001 10111010 11011101
00001010 01001011 10010100 01010100 10100011 01101110
11010111 11110001 01000110 00001101 10011011 10110010

2.5.2.2.6 VDB Signal Tracking Requirements

2.5.2.2.6.1 Carrier Frequency Capture Range

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Frequency Counter (HP 53181A Option 010, or equivalent)

e) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)

f) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

h) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

i) VDB Receiver

j) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-18.

2) Adjust the desired signal power at the VDB receiver input to be S_{min} – 3 dB.

3) Turn the RF signal from the VDB Message/Signal Generator off.

4) Tune the VDB Receiver to 113.000 MHz.

5) Tune the Message/Signal Generator to 113.000 MHz less at least the frequency offset defined in Section 2.2.6.1.

6) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

7) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

8) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Condition

Repeat steps 3 through 8 at a transmitted frequency of 113.000 MHz plus at least the frequency offset defined in Section 2.2.6.1.

The pass/fail outcome of both test frequencies must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

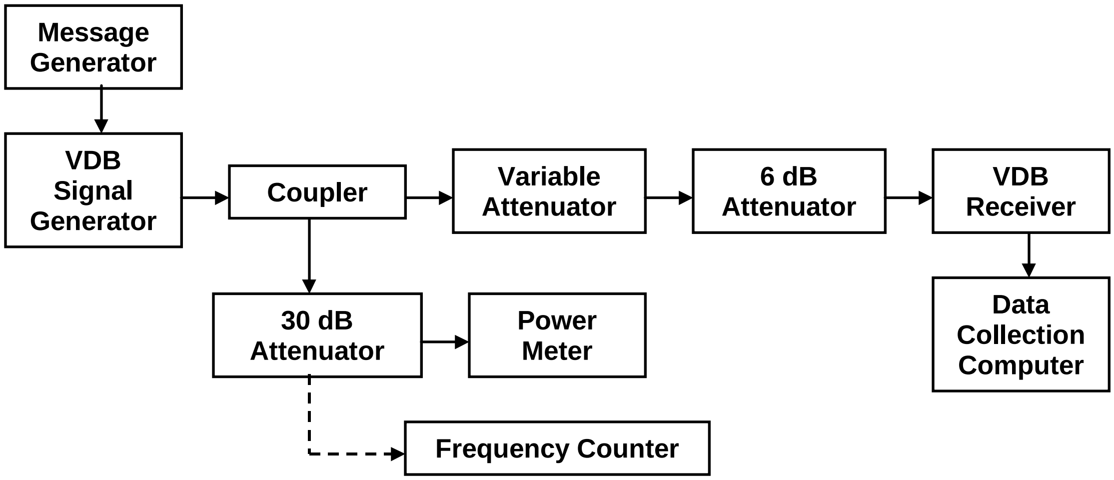


Figure 2-18 Carrier Frequency Capture Range (and Slew Rate) Test Equipment Connection

2.5.2.2.6.2 Carrier Frequency Slew Rate

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Frequency Counter (HP 53181A Option 010, or equivalent)

e) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)

f) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

h) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

i) VDB Receiver

j) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-18.

2) Adjust the desired signal power at the VDB receiver input to be S_{min} – 3 dB.

3) Tune the VDB receiver to 113.000 MHz.

4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3. During this transmission, slew the carrier frequency at a rate of at least that specified in Section 2.2.6.2 between the frequencies 113.000 MHz plus and minus at least the frequency offset defined in Section 2.2.6.1.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

2.5.2.2.6.3 Symbol Rate Tolerance

Equipment List

a) VDB Message/Signal Generator

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

d) Vector Signal Analyzer (HP 89441A, or equivalent)

e) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps)

f) Variable Attenuator (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

h) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

i) VDB Receiver

j) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-19.

2) Adjust the signal power at the VDB receiver input to be S_{min} – 3 dB.

3) Turn the RF signal from the VDB Message/Signal Generator off.

4) Tune the VDB Receiver and VDB Message/Signal Generator to 113.000 MHz.

5) Set the VDB Message/Signal Generator symbol rate equal to or less than the lowest rate specified in Section 2.2.6.3.

6) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

7) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

8) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Condition

Repeat steps 2 through 8 at a symbol rate greater than or equal to the highest rate specified in Section 2.2.6.3.

The pass/fail outcome of both symbol rates must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

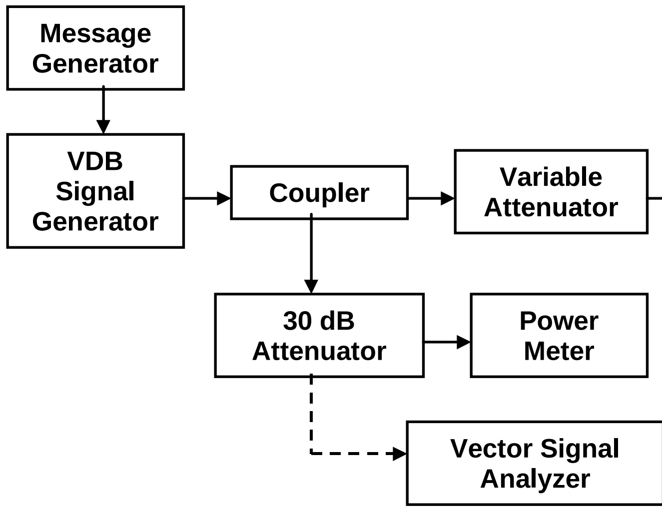


Figure 2-19 Symbol Rate Tolerance Test Equipment Connection

2.5.2.2.7 Co-Channel Rejection

2.5.2.2.7.1 VDB as the Undesired Signal

Equipment List

a) 2 VDB Message/Signal Generators

b) VDB TDMA Synchronizing Timer

c) 2 Coupler(s), 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

d) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

e) Variable Attenuators (HP 855C (0-12 dB, 1 dB steps)

f) Variable Attenuators (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) Signal Splitter/Combiner (HP 11667A, or equivalent)

h) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

i) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

j) VDB Receiver

k) Data Collection Computer

Part A: Detailed Test Procedure for Co-Channel Signals in the Same Slot

1) Connect the equipment as shown in Figure 2-20.

2) Verify that the synchronization of the VDB Signal Generators is within 95.2 microseconds.

3) Adjust the desired signal power at the VDB receiver input to be at the minimum sensitivity specified in S_{min}. Adjust the undesired VDB signal at the VDB receiver input to be below this value by an amount equal to the D/U specified in Section 2.2.7.1 item (a) on the same slot.

4) Tune both of the VDB Message/Signal Generators and the VDB Receiver to 108.000 MHz.

5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3. The two generators must output different messages.

6) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

7) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 7 for each of the test frequencies and power levels listed in Table 2-27.

Table 2-27 Test Conditions for Same Slot Co-Channel VDB Rejection Tests

Received Power	Test Frequencies
S_{min}	108.000, 113.000 and 117.975 MHz
S_{max}	108.000, 113.000, and 117.975 MHz

The pass/fail outcome of all twelve received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

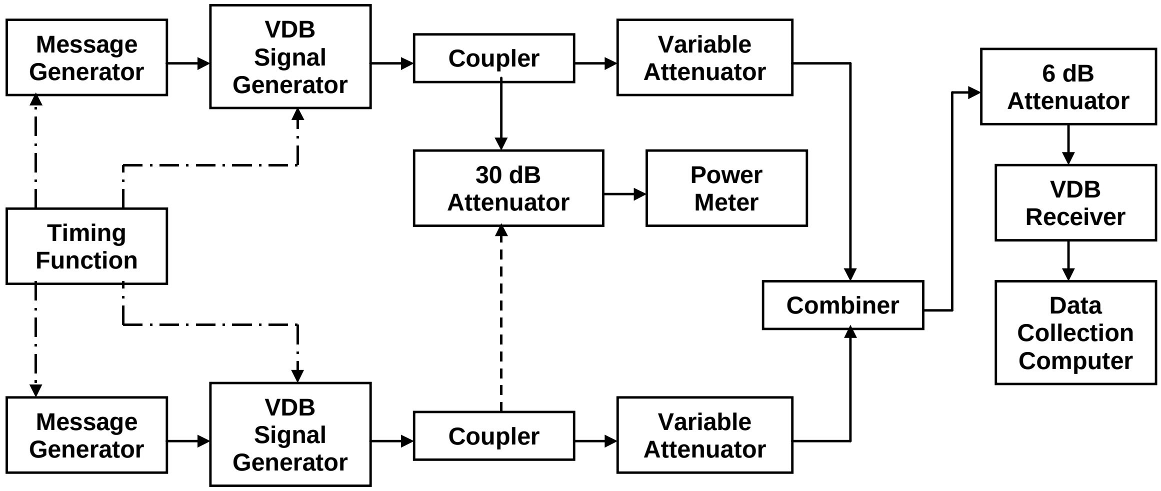


Figure 2-20 **VDB/VDB Co-Channel (and Adjacent Channel) Rejection Test Equipment Connection**

Part B: Detailed Test Procedure for Co-Channel Signals in Adjacent Slots

1) Connect the equipment as shown in Figure 2-20.
2) Adjust the signal power at the VDB receiver input from one of the VDB Signal Generators to the higher power level specified in Section 2.2.7.1, (Part B) and adjust the signal power at the VDB receiver input from the other VDB Signal Generator to S_{min} as specified in Section 2.2.5.
3) Synchronize the two VDB Signal Generators such that the generator set at the lower power level follows in the slot(s) immediately after the slot(s) occupied by the generator at the high power level and verify that the generators are synchronized within 95.2 microseconds.
4) Tune both of the VDB Message/Signal Generators and the VDB Receiver to 108.000 MHz.
5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generators to transmit the number of test messages specified in Section 2.5.2.1.3. The two generators must output different messages.
6) Using the VDB Receiver and Data Collection Computer, determine the MFR of the low signal level slot(s) using the methodology specified in Section 2.5.2.1.3. The VDB Receiver does not need to meet MFR requirements for the high signal level slot(s).
7) Compare the achieved MFR for the low signal level slot(s) with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 7 for test frequencies listed in Table 2-28.

Table 2-28 Test Frequencies for Adjacent Slot Co-Channel VDB Rejection Tests

Test Frequencies
108.000, 113.000 and 117.975 MHz

The pass/fail outcome of all three test frequencies must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

2.5.2.2.7.2 VOR as the Undesired Signal

Equipment List

a) VDB Message/Signal Generators

b) VDB TDMA synchronizing Timer

c) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

d) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

e) Variable Attenuators (HP 855C (0-12 dB, 1 dB steps)

f) Variable Attenuators (HP 355D (0-120 dB, 10 dB steps), or equivalent)

g) VOR Signal Generator (Marconi Instruments, 10 kHz – 2.7 GHz Avionics Signal Generator 2031, or equivalent)

h) Signal Splitter/Combiner (HP 11667A, or equivalent)

i) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

j) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

k) VDB Receiver

l) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-21 with the VOR Signal Generator enabled.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}. Adjust the undesired VOR signal at the VDB receiver input to be below this value by an amount equal to the D/U specified in Section 2.2.7.2 on the same slot.

3) Tune the VDB Message/Signal Generator, VOR Signal Generator, and VDB Receiver to 108.000 MHz.

4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the test frequencies and power levels listed in Table 2-29.

Table 2-29 Test Conditions for Co-Channel VOR Rejection Tests

Received Power	Test Frequencies
S_{min}	108.000, 113.000 and 117.975 MHz
S_{max}	108.000, 113.000, and 117.975 MHz

The pass/fail outcome of all six received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

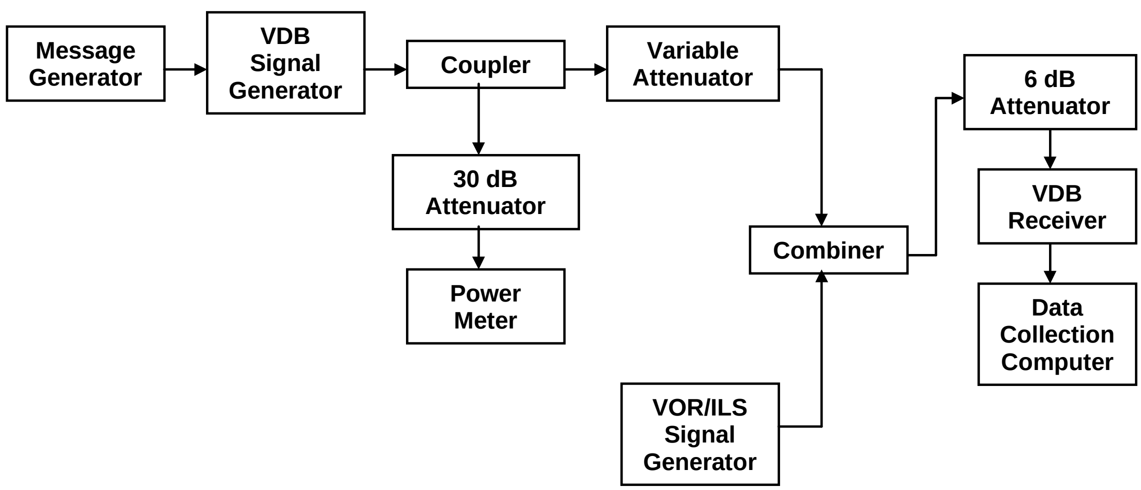


Figure 2-21 VOR (ILS) as the Undesired Signal Test Equipment Connection

2.5.2.2.7.3 ILS Localizer as the Undesired Signal

Equipment List

a) VDB Message/Signal Generators

b) VDB TDMA synchronizing Timer

c) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

d) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

e) Variable Attenuators (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

f) ILS Localizer Signal Generator (Marconi Instruments, 10 kHz – 2.7 GHz Avionics Signal Generator 2031, or equivalent)

g) Signal Splitter/Combiner (HP 11667A, or equivalent)

h) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

i) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

j) VDB Receiver

k) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-21 with the ILS Localizer Signal Generator enabled.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}. Adjust the undesired ILS Localizer signal at the VDB receiver input to be below this value by an amount equal to the D/U specified in Section 2.2.7.3.

3) Tune the VDB Message/Signal Generator, ILS Localizer Signal Generator, and VDB Receiver to 108.100 MHz.

4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the test frequencies and power levels listed in Table 2-30.

Table 2-30 Test Conditions for Co-Channel Localizer Rejection Tests

Received Power	Test Frequencies
S_{min}	108.100, 111.950 MHz
S_{max}	108.100, 111.950 MHz

The pass/fail outcome of all four received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

2.5.2.2.8 Adjacent Channel Rejection

Due to the similarity in the methodology for conducting these tests, this section details the complete set of tests for showing compliance to the adjacent channel requirements.

Equipment List

The equipment list and connections used for the adjacent channel tests for VDB, VOR, and the ILS localizer are the same as those corresponding to Sections 2.5.2.2.7.1, 2.5.2.2.7.2, and 2.5.2.2.7.3, respectively.

Part A: Detailed Test Procedures for VDB as the Undesired Adjacent Channel Signal

1) Connect the equipment as shown in Figure 2-20.
2) Adjust the desired signal power at the VDB receiver input to be S_{min}. For the 1st Adjacent 25 kHz offset case (±25 kHz), adjust the undesired VDB signal at the VDB receiver to provide the D/U specified in Section 2.2.8.1a).
3) Verify that the synchronization of the VDB Signal Generators is within 95.2 microseconds.
4) Tune the desired VDB Message/Signal Generator and VDB Receiver to 108.100 MHz. Tune the undesired VDB Message/Signal Generator to 108.125 MHz (the high-side adjacent channel).
5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.
6) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.
7) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 7 for each of the frequency combinations listed in Table 2-31.

Table 2-31 Test Conditions for 1st Adjacent Channel VDB Rejection Tests

Desired VDB Signal Frequency (MHz)	Low-Side VDB Adjacent Channel (MHz)	High-Side VDB Adjacent Channel (MHz)
108.100	108.075	108.125
113.000	112.975	113.025
117.900	117.875	117.925

The pass/fail outcome of all six test frequencies combinations must be used to determine the ability of the VDB receiver subsystem to meet the tested requirement(s).

Repeat the detailed test procedures for the 2nd Adjacent 25 kHz Channels (±50 kHz) as listed in Table 2-32 and determine the pass/fail outcome. The desired signal level *is* set to S_{min}, with the undesired signal at a level corresponding to the D/U ratio specified in Section 2.2.8.2a).

Table 2-32 Test Conditions for 2nd Adjacent Channel VDB Rejection Tests

Desired VDB Signal Frequency (MHz)	Low Side VDB Adjacent Channel (MHz)	High Side VDB Adjacent Channel (MHz)
108.100	108.050	108.150
113.000	112.950	113.050
117.900	117.850	117.950

Repeat the detailed test procedures for the 3rd Adjacent 25 kHz Channels (±75 kHz) as listed in Table 2-33 and determine the pass/fail outcome. The desired signal level is set to S_{min}, with the undesired signal at a level corresponding to a D/U ratio specified in Section 2.2.8.3a).

Table 2-33 Test Conditions for 3rd Adjacent Channel VDB Rejection Tests

Desired VDB Signal Frequency (MHz)	Low Side VDB Adjacent Channel (MHz)	High Side VDB Adjacent Channel (MHz)
108.100	108.025	108.175
113.000	112.925	113.750
117.900	117.825	117.975

Part B: Detailed Test Procedure for VOR as the Undesired Adjacent Channel Signal

1) Connect the equipment as shown in Figure 2-21 with the VOR Signal Generator enabled.
2) Adjust the desired signal power at the VDB receiver input to be S_{min}. For the 1st Adjacent 25 kHz offset case (±25 kHz), adjust the undesired VOR signal at the VDB receiver to provide the D/U specified in Section 2.2.8.1b).
3) Tune the desired VDB Message/Signal Generator and VDB Receiver to 108.125 MHz. Tune the undesired VOR Generator to 108.150 MHz (the high-side adjacent channel).
4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.
5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.
6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the frequency combinations listed in Table 2-34.

Table 2-34 Test Conditions for 1st Adjacent Channel VOR Rejection Tests

Desired VDB Signal Frequency (MHz)	Low-Side VOR Adjacent Channel (MHz)	High-Side VOR Adjacent Channel (MHz)
108.025	108.000	108.050
113.025	113.000	113.050
117.925	117.900	117.950

The pass/fail outcome of all 6 test frequencies combinations must be used to determine the ability of the VDB receiver subsystem to meet the tested requirement(s).

Repeat the detailed test procedures for the 2nd Adjacent 25 kHz Channels (±50 kHz) as listed in Table 2-35 and determine the pass/fail outcome. The desired signal level is set to S_{min}, with the undesired signal at a level corresponding to the D/U ratio specified in Section 2.2.8.2b).

Table 2-35 Test Conditions for 2nd Adjacent Channel VOR Rejection Tests

Desired Signal Frequency (MHz)	Low Side VOR Adjacent Channel (MHz)	High Side VOR Adjacent Channel (MHz)
108.050	108.000	Not Applicable
108.150	Not Applicable	108.200
113.000	112.950	113.050
117.900	117.850	117.950

Repeat the detailed test procedures for the 3rd Adjacent 25 kHz Channels (±75 kHz) as listed in Table 2-36 and determine the pass/fail outcome. The desired signal level is set to S_{min}, with the undesired signal at a level corresponding to the D/U ratio specified in Section 2.2.8.3b).

Table 2-36 Test Conditions for 3rd Adjacent Channel VOR Rejection Tests

Desired Signal Frequency (MHz)	Low Side VOR Adjacent Channel (MHz)	High Side VOR Adjacent Channel (MHz)
108.075	108.000	Not Applicable
108.175	Not Applicable	108.250
113.075	113.000	113.150
117.875	117.800	117.950

Note: *The VDB desired frequencies are chosen such that the VOR test frequencies correspond to actual assignable VOR channels.*

Part C: Detailed Test Procedure for the ILS Localizer as the Undesired Adjacent Channel Signal

1) Connect the equipment as shown in Figure 2-21 with the ILS Localizer Signal Generator enabled.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}. For the 1st Adjacent 25 kHz offset case (±25 kHz), adjust the undesired ILS Localizer signal at the VDB receiver to provide the D/U specified in Section 2.2.8.1c).

3) Tune the desired VDB Message/Signal Generator and VDB Receiver to 108.125 MHz. Tune the undesired ILS Localizer Signal Generator to 108.150 MHz (the high-side adjacent channel).

4) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

5) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

6) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 6 for each of the frequency combinations listed in Table 2-37.

Table 2-37 Test Conditions for 1st Adjacent Channel Localizer Rejection Tests

Desired VDB Signal Frequency (MHz)	Low-Side ILS Localizer Adjacent Channel (MHz)	High-Side ILS Localizer Adjacent Channel (MHz)
108.125	108.100	108.150
111.925	111.900	111.950

The pass/fail outcome of all four test frequencies combinations must be used to determine the ability of the VDB receiver subsystem to meet the tested requirement(s).

Repeat the detailed test procedures for the 2nd Adjacent 25 kHz Channels (±50 kHz) as listed in Table 2-38 and determine the pass/fail outcome. The desired signal level is set to S_{min}, with the undesired signal at a level corresponding to the D/U ratio specified in Section 2.2.8.2c).

Table 2-38 Test Conditions for 2nd Adjacent Channel Localizer Rejection Tests

Desired Signal Frequency (MHz)	Low Side ILS Localizer Adjacent Channel (MHz)	High Side ILS Localizer Adjacent Channel (MHz)
108.150	108.100	Not Applicable
108.050	Not Applicable	108.100
111.950	111.900	Not Applicable
111.900	Not Applicable	111.950

Repeat the detailed test procedures for the 3rd Adjacent 25 kHz Channels (±75 kHz) as listed in Table 2-39 and determine the pass/fail outcome. The desired signal level is set to S_{min}, with the undesired signal at a level corresponding to the D/U ratio specified in Section 2.2.8.3c).

Table 2-39 Test Conditions for 3rd Adjacent Channel Localizer Rejection Tests

Desired Signal Frequency (MHz)	Low Side ILS Localizer Adjacent Channel (MHz)	High Side ILS Localizer Adjacent Channel (MHz)
108.175	108.100	Not Applicable
108.025	Not Applicable	108.100
111.975	111.900	Not Applicable
111.875	Not Applicable	111.950

Note: *The VDB desired frequencies are chosen such that the ILS Localizer test frequencies correspond to actual assignable ILS Localizer channels.*

Part D: Detailed Test Procedures for Rejection With No On-Channel VDB Signal

1) Connect the equipment as shown in Figure 2-13.
2) Tune the VDB receiver to 108.100 MHz. Do not apply a VDB signal at 108.100 MHz. Tune the undesired VDB Message/Signal Generator to 108.125 MHz (the high-side adjacent channel). Set the signal level of the undesired signal to the level specified in Section 2.2.7.1b).
3) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.
4) Using the VDB Receiver and Data Collection Computer, verify that the VDB receiver does not output data from the undesired signal.
5) Perform Steps 2 through 4 for each of the frequency combinations listed in Table 2-40.

Table 2-40 Test Conditions for Rejection Tests with No On-Channel VDB Signal

Desired VDB Signal Frequency (MHz)	Low-Side VDB Adjacent Channel MHz	High-Side VDB Adjacent Channel (MHz)
108.100	108.075	108.125
113.000	112.975	113.025
117.900	117.875	117.925

6) Analyze the frequency conversion architecture of the receiver to determine whether the receiver has an image frequency or a half-IF frequency that can fall in the frequency range of 108.000 to 117.975 MHz for any valid VDB channel frequency. If one or both of these conditions exist, repeat steps 2 through 4 with the undesired VDB Message/Signal Generator tuned to the image or half-IF frequency for the affected VDB channel frequency or frequencies.

Note: *The term "half-IF frequency" refers to an undesired signal response that is due to mixing of the second harmonic of a local oscillator with the second harmonic of an undesired signal. The undesired signal frequency in this case is located one-half of the Intermediate Frequency (IF) away from the desired signal on the same side as the local oscillator frequency, i.e., half-way between the desired signal frequency and the local oscillator. Example: Selected VDB frequency = 117.000 MHz. IF = 10.700 MHz. With the Local Oscillator on the low side of the desired signal at 106.300 MHz, the half-IF response of the VDB receiver may produce an undesired output from an undesired signal at 111.650 MHz. Mixing of second harmonics yields 2x111.650 - 2x106.300 = 10.700 MHz, which is an undesired mixer output that the IF filter cannot reject. Half-IF rejection is generally dependent on the IF frequency chosen, the mixer design, and filtering prior to the mixer.*

Note: *The VDB receiver design should avoid frequency responses, including image and half-IF responses, that would allow decoding of undesired VDL broadcasts that use similar modulation in the VHF COM frequency band, 118 to 137 MHz.*

2.5.2.2.9 Out-of-Band Rejection

2.5.2.2.9.1 VDB Interference Immunity

Equipment List

a) VDB Message/Signal Generators

b) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

c) Power Meter (HP 8991A with HP 84815A Sensor, or equivalent)

d) Attenuator, 6 dB (HP 11667A Option 006, or equivalent)

e) Attenuator, 30 dB (HP 11667A Option 030, or equivalent)

f) Variable Attenuator (HP 355C (0-12 dB, 1 dB steps) and HP355D (0-120 dB, 10 dB steps), or equivalent)

g) Signal Generator (HP 8648A, or equivalent)

h) Spectrum Analyzer (HP 8566B, or equivalent)

i) Signal Splitter/Combiner (HP 11667A, or equivalent)

Detailed Test Procedure

This is a two-part test. In Part One, analysis and a swept frequency search is performed to identify potential analog image and spurious frequencies and possible digitally induced aliases. The second part evaluates the degradation to a desired signal channel due to CW interference signals on the image and spurious frequencies found in Part One of the test and by analysis. The degradation is evaluated in terms of message failure rate as defined in Sections 2.2 and 2.2.5 and using the criteria defined in Section 2.5.2.1.3.

Prior to the start of the test, analyze the receiver under test to determine required input test frequencies. All intermediate (IF) and reference frequencies used within the receiver must be known. Using these frequencies, calculate all frequencies within the ranges specified in Section 2.2.8.1 which possibly will produce image or spurious signals. The calculations should include image frequencies and mixer harmonic intermodulation distortions which are capable of producing IF frequencies used within the receiver, or sub-harmonics of these IF frequencies, and such frequencies that may lead to digital aliasing problems or other spurious responses.

Part One of this test may be performed with the VDB receiver unit open. In order to perform this test, an analog signal must be available prior to the A/D converter.

Part One:

1) Connect the equipment as shown in Figure 2-22.

2) With the swept CW signal generator turned off, tune the VDB generator to provide an unmodulated test signal at 108.000 MHz at the minimum sensitivity level specified in Section 2.2.5.

3) Tune the VDB receiver to the same frequency.

4) Set the spectrum analyzer sweep to zero span. Set the spectrum analyzer resolution bandwidth and video bandwidth each to 100 Hz.

5) Tune the spectrum analyzer center frequency for maximum response to the receiver's down-converted IF signal, and note the level of this response.

6) Command off the VDB generator test signal. Assure that the signal-to-noise ratio observed on the spectrum analyzer is at least 12 dB (i.e., the indicated level on the spectrum should decrease at least 12 dB from the level noted above). Reduce the spectrum analyzer resolution bandwidth and video bandwidth if needed to obtain this signal-to-noise ratio.

7) Turn on the swept CW signal generator. Adjust its output to produce signal levels into the receiver as specified for each of the frequency ranges given in Section 2.2.8.1. Sweep the frequency over the ranges specified in Section 2.2.8.1. Identify and record any input frequency which produces an observable output above the noise level on the spectrum analyzer.

Part Two:

1) If the VDB receiver was opened for Part One of this test, disconnect the tap into the analog receiver chain and close the unit.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}.

3) Tune the VDB Message/Signal Generator and VDB Receiver to 108.000 MHz.

4) With the swept CW signal generator shown in Figure 2-22, place a CW signal with a level as specified in Section 2.2.8.1 at each frequency, one at a time in sequence, as found either in Part One of this test or by analysis. Repeat the following steps 4, 5, and 6 for each frequency in the sequence.

5) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

6) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

7) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform all of the steps in Part One and Part Two at each of the test frequencies listed in Table 2-41.

Table 2-41 Test Frequencies for VDB Interference Immunity Tests

Test Frequencies
108.000, 113.000, and 117.975 MHz

The pass/fail outcome of the three test frequencies must be used to determine the test disposition. In order to pass the test, the VDB receiver must pass each individual test. Failure of one or more scenarios results in failing this test.

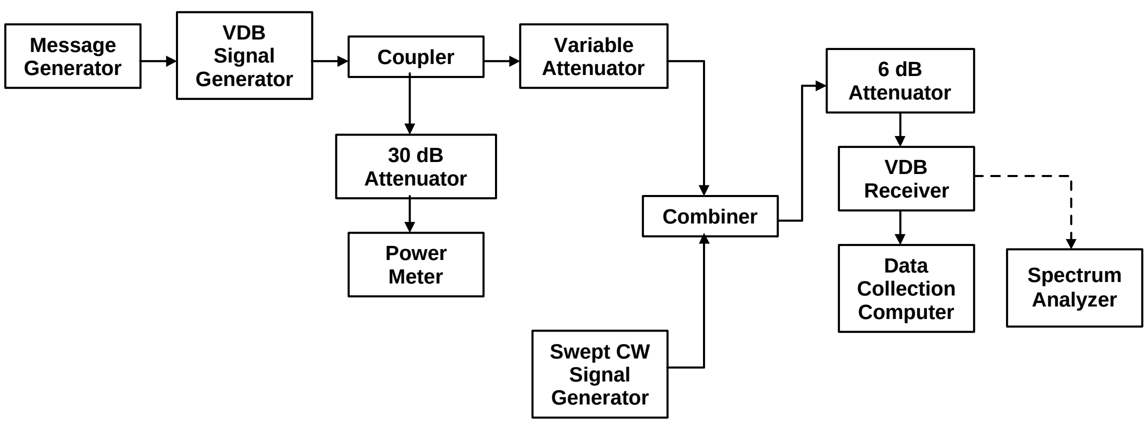


Figure 2-22 Interference Immunity Test Equipment Connection

2.5.2.2.9.2 FM Immunity

2.5.2.2.9.2.1 Desensitization

Equipment List

a) VDB Message/Signal Generator

b) Timing Function

c) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

d) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

e) Audio Noise Generator

f) FM Signal Generator (Marconi Instruments, 10 kHz - 2.7 GHz Avionics Signal Generator 2031, or equivalent)

g) Power Amplifier (Mini-Circuits, ZHL-5W-1, or equivalent)

h) Filter (Decibel, DB4013-2 88 MHz Cavity Bandpass)

i) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

j) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

k) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

l) Signal Splitter/Combiner (HP 11667A, or equivalent)

m) VDB Receiver

n) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-23.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}.

3) Tune the VDB Message/Signal Generator and VDB Receiver to 108.025 MHz.

4) With the Audio Noise Generator enabled, tune the FM Signal Generator to 107.700 MHz.

5) Adjust the power of the FM Signal Generator to the level specified in Section 2.2.9.2 for the indicated FM test frequency at the VDB Receiver input.

6) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

7) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

8) Compare the achieved and Data Collection Computer, determine the MFR with that specified in Section 2.5.2.1.2 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 8 for each of the received power and test frequency combinations listed in Table 2-42.

Table 2-42 Test Conditions for Desensitization Tests

VDB Signal Frequency (MHz)	FM Signal Frequency (MHz)	FM Signal Power at the VDB Rx Input (dBm)
108.025	107.700	See Table 2-3
108.075	107.900	See Table 2-3
111.975	107.900	See Table 2-3
108.025	106.000	See Table 2-3
111.975	106.000	See Table 2-3
108.025	104.000	See Table 2-3
111.975	104.000	See Table 2-3
108.025	88.000	See Table 2-3
111.975	88.000	See Table 2-3
112.000	107.900	See Table 2-4
117.950	107.900	See Table 2-4
112.000	106.000	See Table 2-4
117.950	106.000	See Table 2-4
112.000	104.000	See Table 2-4
117.950	104.000	See Table 2-4
112.000	88.000	See Table 2-4
117.950	88.000	See Table 2-4

Note: *The frequencies chosen for these tests do not necessarily correspond to actual assignable commercial FM broadcast stations.*

The pass/fail outcome of all received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

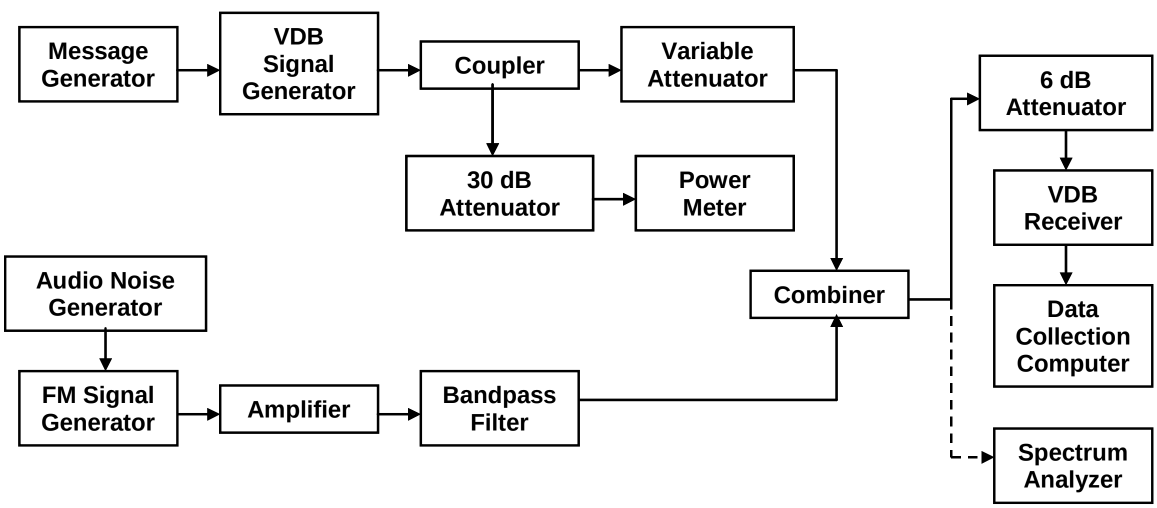


Figure 2-23 Desensitization Test Equipment Connection

2.5.2.2.9.2.2 Intermodulation Rejection

Equipment List

a) VDB Message/Signal Generator

b) Timing Function

c) Coupler, 20 dB, 0.1-2 GHz (HP 778D, or equivalent)

d) Power Meter (HP 8991A, with HP 84815A sensor, or equivalent)

e) Pink Noise or CCIR Colored Audio Noise Generator

f) FM Signal Generator (Marconi Instruments, 10 kHz – 2.7 GHz Avionics Signal Generator 2031, or equivalent)

g) CW Signal Generator (Marconi Instruments, 10 kHz – 2.7 GHz Avionics Signal Generator 2031, or equivalent)

h) 2 Power Amplifiers (Mini-Circuits, ZHL-5W-1, or equivalent)

i) 2 Filters (Decibel, DB4013-2 88 MHz Cavity Bandpass)

j) Variable Attenuator (HP 855C (0-12 dB, 1 dB steps) and HP 355D (0-120 dB, 10 dB steps), or equivalent)

k) 30 dB Attenuator (HP 8491A Option 030, or equivalent)

l) 6 dB Attenuator (HP 8491A Option 006, or equivalent)

m) 2 Signal Splitter/Combiners (HP 11667A, or equivalent)

n) VDB Receiver

o) Data Collection Computer

Detailed Test Procedure

1) Connect the equipment as shown in Figure 2-24.

2) Adjust the desired signal power at the VDB receiver input to be S_{min}.

3) Tune the VDB Message/Signal Generator and VDB Receiver to 108.100 MHz.

4) With the Audio Noise Generator enabled, tune the FM Signal Generator to 107.700 MHz and the CW Signal Generator to 107.300 MHz.

5) Adjust the power of the FM and CW Signal Generators to each be at the level specified in Section 2.2.9.2.2 at the VDB Receiver input.

6) Using the message format specified in Section 2.5.2.1.2, command the VDB Message/Signal Generator to transmit the number of test messages specified in Section 2.5.2.1.3.

7) Using the VDB Receiver and Data Collection Computer, determine the MFR using the methodology specified in Section 2.5.2.1.3.

8) Compare the achieved MFR with that specified in Section 2.5.2.1.3 to determine the pass/fail status of the VDB receiver subsystem for this test condition.

Additional Test Conditions

Perform steps 4 through 8 for each of the received power and test frequency combinations listed in Table 2-43.

Table 2-43 Test Conditions for Intermodulation Rejection Tests

FM Signal Frequency (MHz)	CW Signal Frequency (MHz)	Power at the VDB Rx Input (dBm)
107.700	107.300	see Section 2.2.9.2.2
103.000	97.900	see Section 2.2.9.2.2
98.000	87.900	see Section 2.2.9.2.2

Note: *The frequencies chosen for this test do not necessarily correspond to actual assignable commercial FM broadcast stations.*

The pass/fail outcome of all three received power and test frequency combinations must be used to determine the test disposition. In order to pass the test, the VDB receiver subsystem must pass each individual test. Failure of one or more test scenarios results in failing this test.

Note: *In Step 5 above, the use of one CW carrier and one modulated carrier simulates a typical case of FM intermodulation interference to the VDB receiver. This typical case occurs on a regular basis whenever one or the other of the two FM stations causing the third-order intermodulation has momentary pauses in its audio, e.g., momentary dead time between words, sentences, or pauses in speech or music. If both signals were simultaneously modulated, the intermodulation energy would be spread wider in the spectrum and would, therefore, introduce less interference in the bandwidth of the VDB receiver. Pink noise or CCIR colored noise simulates voice and music spectral characteristics.*

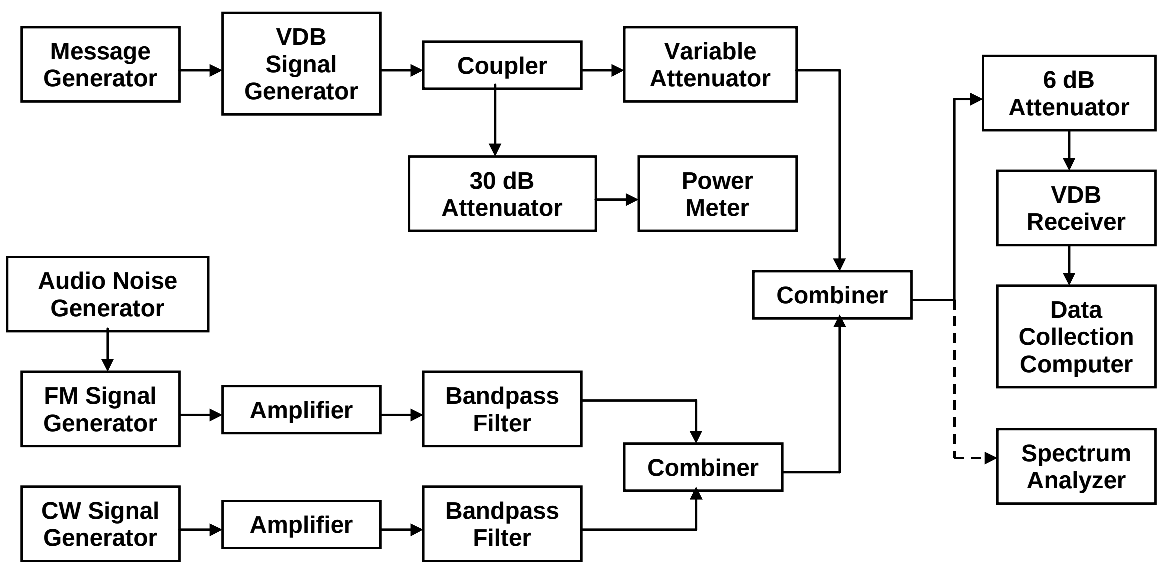


Figure 2-24 FM Broadcast Intermodulation Rejection Test Equipment Connection

2.5.2.2.10 Receiver-to-Antenna Interface

2.5.2.2.10.1 Receiver Voltage Standing Wave Ratio (VSWR)

Equipment List

a) Network Analyzer (HP 8751A with HP 87511A S-Parameter Test Set, or equivalent)

Detailed Test Procedures

1) Tune the receiver to 108.000 MHz
2) Using the network analyzer, calibrate the test setup to account for the loss in the RF cable to be used to connect the network analyzer to the receiver. Then connect that cable to the receiver's antenna input terminals. The level of the signal applied to the receiver should not overload the receiver's input circuit per the maximum signal level S_{max}.
3) Measure the VSWR at the input of the receiver at 108.000 MHz and verify compliance with the requirements in Section 2.2.10.1.

Additional Test Conditions

Perform steps 1 through 3 for each of the test frequencies listed in Table 2-44.

Table 2-44 Test Frequencies for Receiver VSWR Tests

Test Frequencies
108.000, 113.000, and 117.975 MHz

The pass/fail outcome of the three test frequencies must be used to determine the test disposition. In order to pass the test, the antenna must pass each individual test. Failure of one or more scenarios results in failing this test.

2.5.2.2.10.2 Antenna Characteristics

2.5.2.2.10.2.1 Horizontal Polarized Antenna

2.5.2.2.10.2.1.1 Horizontal Antenna Gain

Equipment List

a) Antenna ground plane (1.22 m (4 feet) diameter, or larger)
b) Two standard half-wave dipole antennas (1.27 cm (1/2 inch) diameter, 1.27 m (50 inches in length) adjusted for resonance at 113.000 MHz, of aluminum, or equivalent)
c) Matching stubs, or equivalent matching device
d) Network Analyzer (HP 8751A with HP 87511A S-Parameter Test Set, or equivalent)

Detailed Test Procedures

Part A:

1) Refer to Figure 2-25. Mount a standard dipole antenna in a horizontal position at the center of the ground plane. Elevate the dipole 25.4 cm (10 inches) above the ground plane, using a non-conductive pedestal, such as polystyrene.

2) Match the standard dipole for a VSWR of 1.2:1, or less, at the transmission line impedance, using the tuning stubs or equivalent device, at a frequency of 113.000 MHz.

3) Mount a second standard dipole antenna horizontally with respect to the ground, located at least 15 m (50 feet) from the dipole and at the same elevation. Rotate the standard dipoles for maximum coupling of radiation from one antenna to the other. (The axis of both of the standard dipoles should be perpendicular in the horizontal plane to a line connecting the two antennas.)

4) Using the network analyzer, record the net loss (S21 or S12 in dB) of the test system with the two standard dipoles. Record the relative positions of the standard dipoles.

5) Refer to Figure 2-26. Mount the antenna to be tested in the prescribed manner in place of the standard dipole over the ground plane and its elevating pedestal. Maintain the same relative positions between the antennas as was recorded in the previous step.

6) Using the network analyzer, record the net loss (S21 or S12 in dB) of the test system with the antenna to be tested and the remaining standard dipole in the forward and backward directions relative to the antenna being tested. Compare these loss values with the loss values measured with the two standard dipoles recorded in Step 4 above and verify compliance with the requirements of Section 2.2.10.2.1.1a).

Part B:

Using the test system as configured in Step 5 of Part A above, rotate the ground plane and the antenna being tested and record the net loss (S21 or S12 in dB) as a function of azimuth in 30 degree increments in the horizontal plane. Compare all minimum and maximum loss values to verify compliance with the requirements of Section 2.2.10.2.1.1b.

Additional Test Conditions

Perform the all the steps in Parts "A" and "B" above for each of the frequencies listed in Table 2-45.

Table 2-45 Test Frequencies for Horizontal Antenna Gain Tests

Test Frequencies
108.000, 113.000, and 117.975 MHz

The pass/fail outcome of the three test frequencies must be used to determine the test disposition. In order to pass the test, the antenna must pass each individual test. Failure of one or more scenarios results in failing this test.

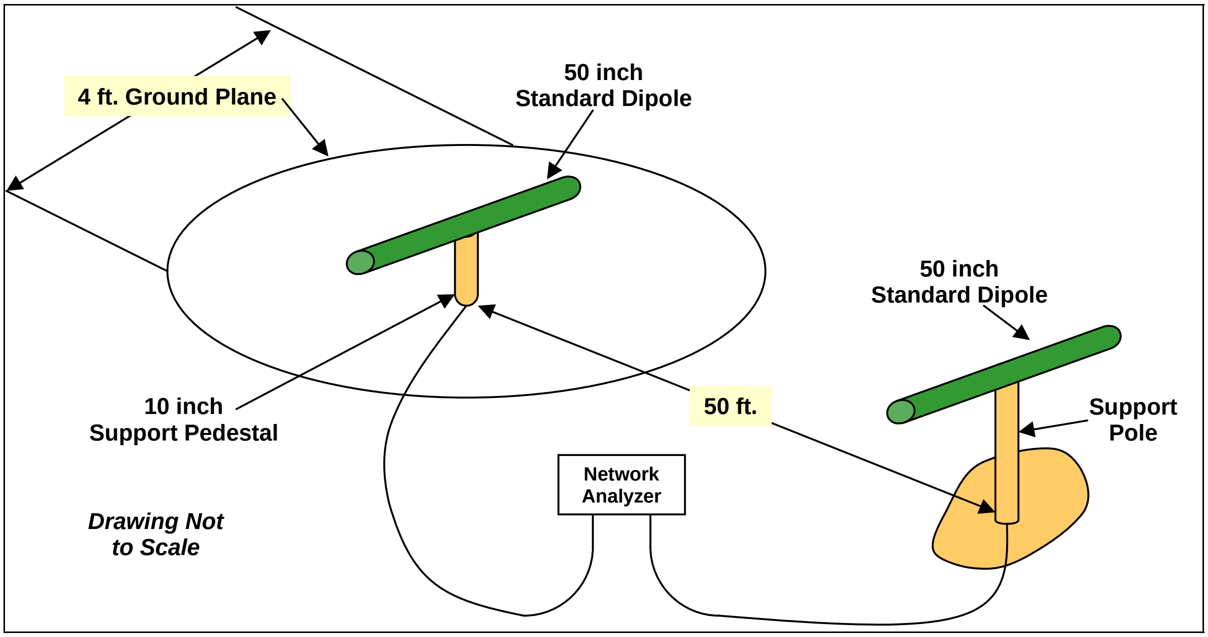


Figure 2-25 **Horizontal (Standard Dipole) Antenna Gain Test Configuration**

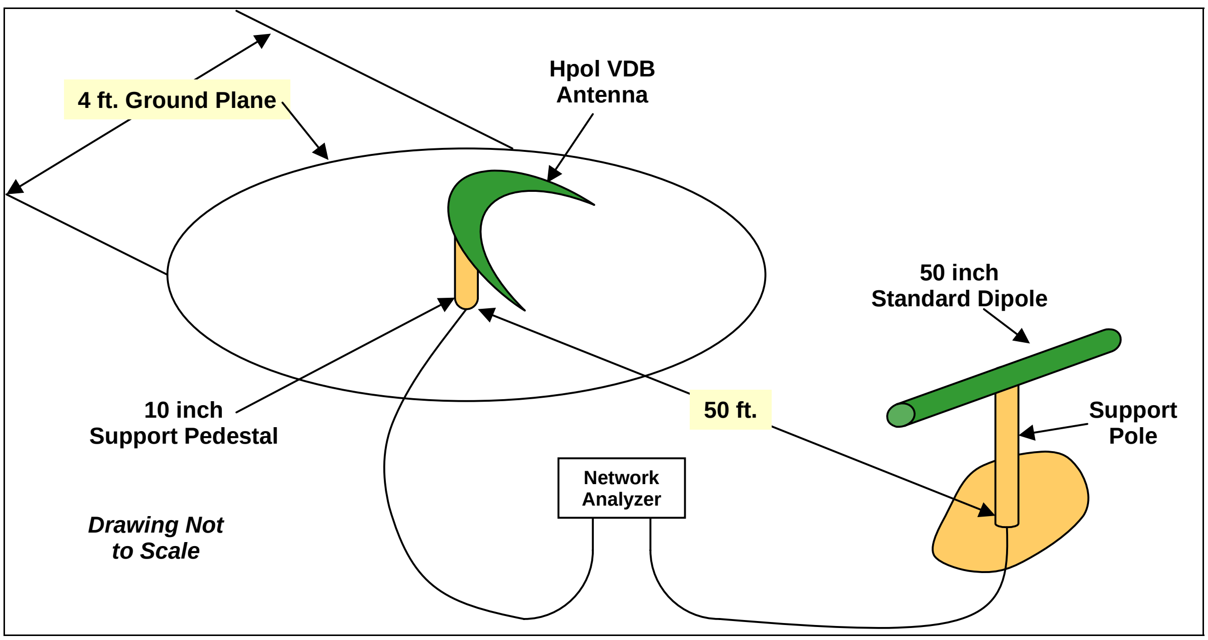


Figure 2-26 **Horizontal (VDB) Antenna Gain Test Configuration**

2.5.2.2.10.2.1.2 Horizontal Antenna VSWR

Equipment List

a) Ground Plane

b) Network Analyzer (HP 8751A with HP 87511A S-Parameter Test Set, or equivalent)

Detailed Test Procedures

1) Using the network analyzer, calibrate the test setup to take account of the loss in the RF cable to be used to connect the network analyzer to the antenna to be tested. Then connect that cable to the antenna's terminals.

2) Record the VSWR of the antenna over the specified frequency range and verify compliance with the requirements in Section 2.2.10.2.1.2.

2.5.2.2.10.2.2 Vertical Polarized Antenna Characteristics

2.5.2.2.10.2.2.1 Vertical Antenna Gain

Equipment List

a) Antenna ground plane (1.22 m (4 feet) diameter, or larger)

b) Standard quarter-wave monopole antenna (1.27 cm (1/2 inch) diameter, 63.5 cm (25 inches) in length adjusted for resonance at 113.000 MHz, of aluminum, or equivalent)

c) Standard half-wave dipole antenna (1.27 cm (1/2 inch) diameter, 1.27 m (50 inches) length adjusted to 113.000 MHz, of aluminum, or equivalent)

d) Matching stubs, or equivalent matching device

e) Network Analyzer (HP 8751A with HP 87511A S-Parameter Test Set, or equivalent)

Detailed Test Procedures

Part A:

1) Refer to Figure 2-27 for a test setup using a standard monopole antenna. Mount the standard monopole antenna in a vertical position in the center of the ground plane.

2) Match the standard monopole antenna for an SWR of 1.2:1, or less, at the transmission line impedance, using the tuning stubs or equivalent device, at a frequency of 113.000 MHz.

3) Mount the standard dipole antenna oriented vertically with respect to the ground and locate it at least 1.27 m (50 inches) from the monopole antenna at the same elevation.

4) Using the network analyzer, record the net loss (S21 or S12 in dB) of the test system with the standard monopole antenna and the standard dipole at 113.000 MHz. Record the relative positions of the standard antennas.

5) Refer to Figure 2-28. Mount the antenna to be tested in the prescribed manner in place of the standard monopole antenna on the ground plane. Maintain the same relative positions between the antennas as was recorded in the previous step.

6) Rotate the ground plane and the antenna being tested and record the net loss (S21 or S12 in dB) of the test system with the antenna to be tested and the standard dipole as a function of azimuth in 30 degree increments in the horizontal plane at 113.000 MHz. Compare these loss values with the loss values measured with the two standard antennas recorded in Step 4 above and verify compliance with the requirements of Section 2.2.10.2.2.1a).

Part B:

Using the test data from Step 6 of Part A above, compare minimum and maximum loss values to verify compliance with the requirements of Section 2.2.10.2.2.1b).

Additional Test Conditions

Perform the all the steps in Parts "A" and "B" above for each of the frequencies listed in Table 2-46.

Table 2-46 Test Frequencies for Vertical Antenna Gain Tests

Test Frequencies
108.000, 113.000, and 117.975 MHz

The pass/fail outcome of the three test frequencies must be used to determine the test disposition. In order to pass the test, the antenna must pass each individual test. Failure of one or more scenarios results in failing this test.

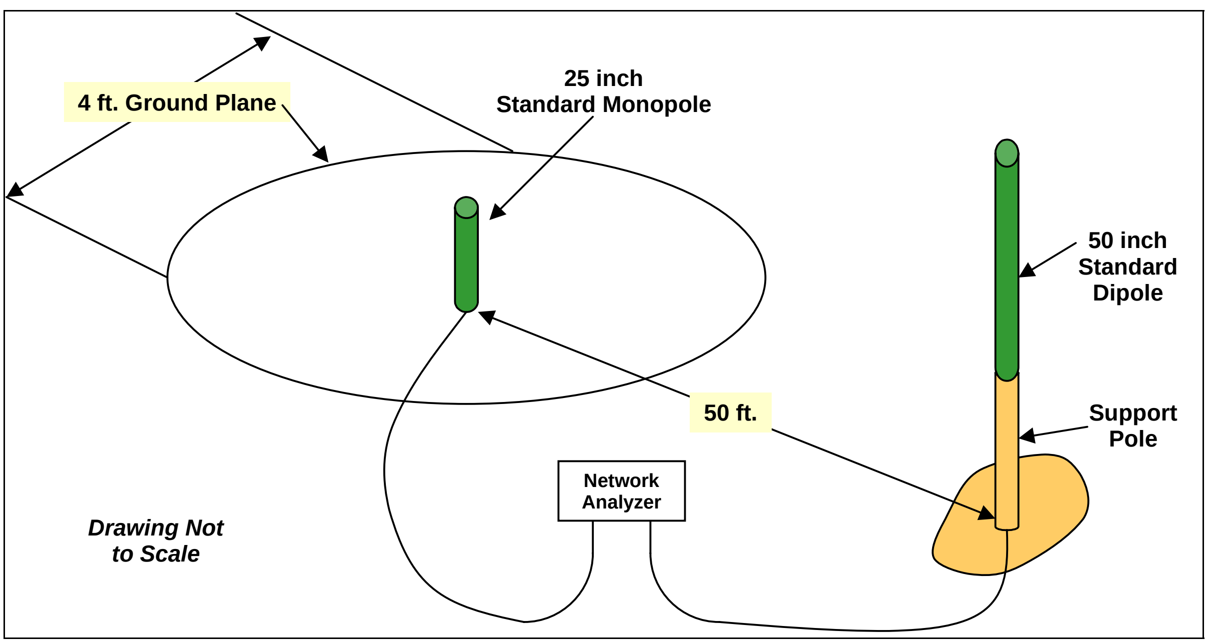


Figure 2-27 Vertical (Standard Dipole) Antenna Gain Test Configuration

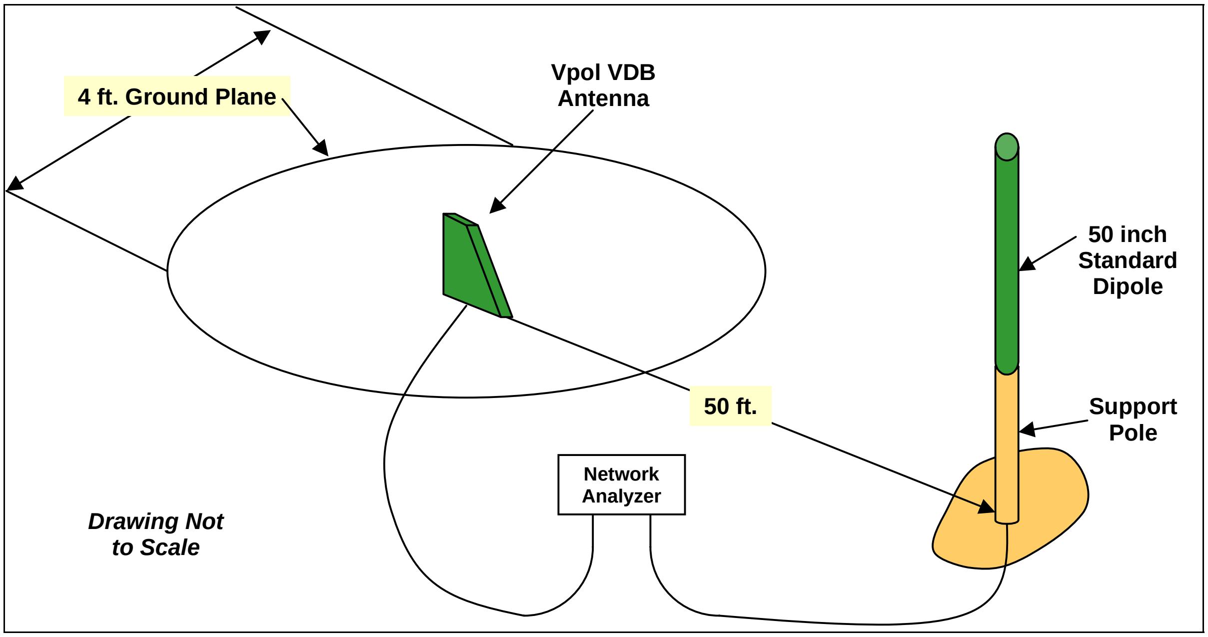


Figure 2-28 **Vertical (VDB) Antenna Gain Test Configuration**

2.5.2.2.10.2.2.2 Vertical Antenna VSWR

Equipment List

a) Ground Plane

b) Network Analyzer (HP 8751A with HP 87511A S-Parameter Test Set, or equivalent)

Detailed Test Procedures

1) Using the network analyzer, calibrate the test setup to take account of the loss in the RF cable to be used in connecting the network analyzer to the antenna to be tested. Then connect that cable to the antenna's terminals.

2) Record the VSWR of the antenna over the specified frequency range and verify compliance with the requirements in Section 2.2.10.2.2.2.

2.5.3 Precision Approach Navigator Tests

2.5.3.1 Definition of PAN Test Terms and Conditions

2.5.3.1.1 Standard Test Signals and Simulator Requirements

Simulated GPS ranging-sources shall *[LAAS-212]* conform with the GPS Standard Performance Standard and Navstar GPS Interface Specification (IS-GPS-200D with IRN-200D-001). Simulated SBAS signals (if needed) shall *[LAAS-213]* conform to the specification for the Wide Area Augmentation System (FAA-E-2892B, Change 2) and Appendix A of DO-229().

Note: *The development of software to RTCA/DO-178B includes tool qualification of the GPS/LAAS simulator.*

Unless otherwise specified, simulated LAAS VDB signals shall *[LAAS-214]* conform to the GPS/LAAS ICD, DO-246().

Unless otherwise specified, all GPS and SBAS signals (if needed) will not indicate unhealthy, erroneous, failed, abnormal, or marginal conditions.

When VDB data or signal is provided for testing of the PAN functions, the data may be provided either by generating a simulated VDB RF signal and processing it using the VHF receiver, or by generating simulated LAAS ICD messages (Types 1, 2, and 4) and providing them to an appropriate input port. Unless otherwise specified, appropriate tuning and channel selection information is provided.

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 *[LAAS-310]* have a bandwidth greater than the RF bandwidth of the equipment under test. $I_{GNSS,Test}$ is defined as the broadband noise needed to ensure that the total effective noise (including the intra-system noise produced by the interfering satellites actually simulated during the test procedure) equals the values specified in Appendix D. The pulse interference source requires an on/off ratio of 154 dB in order to achieve the necessary isolation. The CWI generator shall *[LAAS-219]* be accurate to within 1 kHz.

The signal and interference levels cited in the following test procedures are defined with respect to the input of the antenna preamplifier. The test set-up must include a test amplifier, that has the same gain as the active portion of the antenna. If any interference is inserted after the test amplifier, the interference level must be adjusted to reflect the expected interference at the insertion point. The minimum or maximum installation loss (as appropriate for the test case) must be included in the test setup, using passive devices. This accounts for the noise generated by the aircraft cabling. When using a specific antenna, the satellite signal levels at the test preamplifier input are adjusted based on the minimum antenna radiation pattern above five degrees; the maximum antenna radiation pattern (taking into account the satellite gain characteristics); and the CW interference levels, adjusted by the minimum frequency selectivity of the specific antenna/preamplifier.

The test signals presented to the equipment under test, unless otherwise specified, shall *[LAAS-311]* account for the minimum preamplifier gain and maximum loss (L_{max}) between the antenna port and the receiver port. Unless otherwise specified, the interference tests are conducted with one satellite at maximum power (-121 dBm which includes maximum combined satellite and antenna radiation pattern gain), one satellite at minimum power (-134 dBm which includes minimum radiation pattern gain), and remaining satellites 3 dB above the satellite at minimum power.

For interference tests conducted with all satellites at maximum power, the test signals presented to the equipment under test shall *[LAAS-312]* be the maximum input signal at the receiver port accounting for the maximum preamplifier gain and minimum fixed loss (L_{min}) between the antenna port and the receiver port.

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}. The test setup must ensure that:

$$[10^{I_{Simulator}/10} + 10^{I_{NG}/10} + 290k(10^{NF_{Amp}/10} - 1)] \geq$$
$$[10^{N_{sky,antenna}/10} + 10^{I_{GNSS,Test}/10} + 10^{I_{Ext,Test}/10}]$$

Note that additional noise is included in the test from the GNSS signals that are simulated and from the noise contribution of the loss block.

<u>Notes</u>:

1) *The specified test procedures provide a representative level of self-interference when acquiring, re-acquiring, and tracking the minimum signal. The test represents a reasonable baseline scenario with respect to self-interference caused by C/A code GPS and SBAS signals, P(Y) and Earth Coverage M code GPS signals, Galileo signals, and QZSS signals.*

2) *Authorized emissions are regulated to a level below the external interference levels (as described in <u>Appendix D</u>) to provide a safety margin.*

3) *The GNSS inter/intra system interference environment is consistent with RTCA/DO-235B.*

4) *Refer to Appendix H for examples of the broadband noise calibration.*

2.5.3.2 Accuracy

The purpose of the Accuracy Test is to validate that the equipment meets the accuracy requirements of Section 2.3.6.8 under the specified interference conditions. It is also intended to verify that the σ_{noise} used in the protection level equations are appropriate bounds on the residual errors allocated to the receiver tracking performance.

<u>Note</u>: *This evaluation method is based on the assumption that a least-squares position algorithm (per Section 2.3.9) is implemented. If a different form of positioning is used, this evaluation method may not be appropriate.*

2.5.3.2.1 Simulator and Interference Conditions

The simulation and interference conditions shall *[LAAS-220]* conform to the following requirements:

a) For all test scenarios, the broadband GNSS test noise and $N_{sky,antenna}$ shall *[LAAS-313]* be simulated. There are three sets of interference test scenarios: broadband external interference noise, Continuous Wave Interference, and pulsed interference.

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

   2) The CW power and frequencies are listed in Table 2-47.

   3) 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 μs, and duty cycle of 1% shall *[LAAS-222]* be used. This corresponds to an I/S ratio of +144 dB for GPS and SBAS satellites.

b) 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 Appendix D.2.3). This GNSS Noise was derived for GPS tracking but is used in the test for both GPS and SBAS tracking to allow simultaneous testing of GPS and SBAS thereby reducing test time. However it is acceptable to run the SBAS testing separately using a total GNSS Noise (I_{GNSS}) of -172.8 dBm/Hz for accuracy verification and/or collection of the SBAS message loss rate data. 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 2-48 (I_{GH}, I_{GL}, I_{SH}, and I_{SL}) is removed for each satellite present. The number of maximum power GPS satellites is N_{GH}, the number of minimum power GPS 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:

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

where:

$$I_{Test} = 10\log10[(N_{GL})10^{IGL/10} + (N_{GH})10^{IGH/10} + (N_{SL})10^{ISL/10} + (N_{SH})10^{ISH/10}]$$

<u>Note</u>: *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 H for an explanation of how I_{Test} is derived and examples of the computation of $I_{GNSS,Test}$ and how it may be applied.*

c) Simulated GPS and SBAS RF shall *[LAAS-223]* be at the minimum power level for the equipment (as described in Section 2.3.6.2), except for the broadband external interference noise case that shall *[LAAS-224]* be tested at the maximum power level (as described in Section 2.3.6.2) as well as the minimum power level. For test cases that require the minimum power level, one GPS satellite shall *[LAAS-314]* 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 for the satellite at maximum power are not used in the evaluation. The scenario shall *[LAAS-225]* include PRN 6 because it is used in the definition of the CWI frequency.

d) Equipment capable of SBAS ranging shall *[LAAS-226]* comply with the following: for all conditions during the portion of the test where accuracy is evaluated at least two SBAS satellites shall *[LAAS-227]* be used.

Note: *The steady-state accuracy test will include a total of ten cases, including minimum satellite RF power level with the broadband interference, seven CW interference conditions listed in Table 2-47, the pulsed interference condition, and the maximum satellite RF power level with the broadband interference.*

e) The total duration of each test case test shall *[LAAS-229]* 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 σ_{noise}.

Table 2-47 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***	+8.0	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 antenna, the frequency selectivity is specified in Appendix D.3 (derived from RTCA/DO-301). When using a specific antenna, its minimum frequency selectivity can be used when determined in accordance with RTCA/DO-301.

** The nominal CWI frequency tested shall *[LAAS-230]* be 20 Hz ± 5 Hz offset below the 3rd spectral line below the carrier frequency of PRN 6 (i.e., 3020 Hz offset from the carrier frequency). The CWI must be synchronized to the satellite signal provided. This exact frequency relationship must be maintained throughout the test.

*** This is required for compatibility 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 2-48 Satellite Equivalent Power Spectral Density

Satellite Type	Maximum Power Satellite	Minimum Power Satellite
GPS	I_{GH} = -183.5 dBm/Hz	I_{GL} = -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 D.

2.5.3.2.2 Test Procedure

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

b) The simulator scenario shall *[LAAS-231]* be engaged and the satellites RF shall *[LAAS-232]* be turned on.

c) The equipment under test shall *[LAAS-233]* 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.

d) When the unit is navigating, the interference to be applied shall *[LAAS-234]* be applied to the equipment under test, and the power of the interference shall *[LAAS-235]* 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 g) below.

e) When steady-state accuracy is reached, 50 independent samples of pseudorange data are recorded at the required sampling interval.

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)].

f) 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):

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

where:

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

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

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

where:

PR_{ij} = smoothed pseudorange, 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

$\sigma_{noise,ij}$ = refer to Section 2.3.12.1

Note: *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.*

g) Verification of σ_{noise} overbounding: The error statistic is compared to the 110% Pass Threshold of Table 2-49 based on the Number of Independent Samples (NIS), where NIS is given by:

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

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 *[LAAS-236]* 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 *[LAAS-237]* 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 H.

h) Steady-state value of σ_{noise}: Using only those samples collected during steady-state operation, the average σ_{noise} output values for each satellite are compared to the requirements of Section 2.3.12.1. The output values must be less than or equal to the required values for the accuracy designator of the equipment.

i) Verification of RMS accuracy: The steps defined in paragraphs f) and g) are repeated using only those samples collected during steady-state operation and using the required RMS accuracy instead of the output $\sigma_{noise,i,j}$ in the computation of $\sigma_{norm,i,j}$. The pass criteria defined in section g) applies.

Table 2-49 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: 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.

2.5.3.2.3 SBAS Tracking Bias

The SBAS tracking bias is caused by differences in net group delay through the receiver correlator that result from the signal bandwidth of the SBAS satellite as compared to a GPS satellite. It is not observable in a satellite simulator that does not mimic the unique signal characteristics of the SBAS satellites, and is difficult to isolate in live signal tests due to the other error contributions (e.g., multipath). Therefore, this effect is identified through analysis.

The filtering characteristics of the equipment must be identified as an input to the analytical model. This characterization should be accomplished through a combination of test and analysis, where sample articles are tested to determine the net effects and the expected variation due to production tolerances is taken into account. The contribution of a standard antenna/preamplifier to the antenna port can be neglected as it is bound to 25 ns relative group delay across the band.

The SBAS satellite characteristics are based on the characteristics of the first-generation WAAS satellites (Inmarsat III) and second-generation WAAS satellites. An acceptable tool to support analyzing the SBAS tracking bias caused by differences in the group delay through the receiver is described in Appendix T of DO-229D.

2.5.3.3 Interference Rejection

2.5.3.3.1 Simulator and Interference Conditions

These tests are intended to verify the performance of the sensor in the presence of in-band continuous-wave interference conditions at and above the levels of Appendix D. Tests shall *[LAAS-238]* be run for each of the GPS or GPS/SBAS signal generator (simulator) scenarios described below:

The simulation and interference conditions shall *[LAAS-239]* conform to the following two requirements:

a) Simulated GPS RF shall *[LAAS-240]* be at the minimum power level for the equipment (as described in Section 2.3.6.2). Other satellites shall *[LAAS-315]* be at a high power level to minimize the effect of interference on their pseudorange. The scenario shall *[LAAS-241]* include PRN 6 because it is used in the definition of the CWI frequency.

b) The nominal CWI frequency tested shall *[LAAS-242]* be 20 Hz ± 5 Hz offset below the 3rd spectral line below the received carrier frequency of PRN 6 (i.e., 3020 Hz offset from the carrier frequency). This exact frequency relationship must be maintained throughout the test. The initial CW power shall *[LAAS-243]* be -120.5 dBm (may be reduced during initial acquisition). The I/S ratio will be varied according to the test procedures.

Note: This evaluation method is based on the assumption that a 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.

2.5.3.3.2 Test Procedures

a) The CW interference to be applied shall *[LAAS-244]* 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.

b) The simulator scenario shall *[LAAS-245]* be engaged and the satellites RF shall *[LAAS-246]* be turned on.

c) The airborne equipment shall *[LAAS-247]* 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.

d) The sensor shall *[LAAS-248]* be allowed to reach steady state. When the sensor has reached steady state, the power of the interference shall *[LAAS-271]* be adjusted to -120.5 dBm.

e) The CW interference power shall *[LAAS-249]* be maintained until the accuracy has reached steady state. Pseudorange measurements and pseudorange validity indication (e.g., isolation bit) for all satellites shall *[LAAS-250]* be recorded during this interval.

f) The power of the CW interfering signal shall *[LAAS-251]* be increased by 1 dB and maintained for 200 seconds. Pseudorange measurements and pseudorange validity indication for all satellites shall *[LAAS-252]* be recorded during this interval.

g) Go to Step f) and repeat until PRN 6 has been excluded from the navigation solution. Increase the interfering signal another 3 dB and verify that PRN 6 is still excluded.

2.5.3.3.3 Pass/Fail Determination

For each sample when the PRN 6 pseudorange is declared valid, the following error criterion shall *[LAAS-253]* be evaluated:

$$Z_j \le 5.33\left(\frac{N_j - 1}{N_j}\right)\sigma_{noise,PRN6,j}$$

where:

$$Z_j \equiv PR_{PRN6,j} - R_{PRN6,j} - (c\Delta t)_j$$

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

where:

PR_{ij} = smoothed pseudorange, 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

$\sigma_{noise,ij}$ = refer to Section 2.3.12.1

If the error criterion is exceeded for more than 6 seconds while PRN 6 is not excluded from the navigation solution, the test is failed.

2.5.3.4 Velocity Accuracy and Velocity Figure of Merit Tests

The purpose of GNSS velocity accuracy test is to characterize the 95% horizontal and 95% vertical velocity accuracies during normal maneuvers as specified in this MOPS.

The tests to verify velocity accuracy performance shall *[LAAS-373]* be run for each of the scenarios described below for all operating modes of the receiver where a valid position and/or velocity could be output by the receiver.

The tests to verify velocity figure of merit shall *[LAAS-374]* be run for each of the scenarios described below for only operating modes of the receiver where velocity figure of merits could be output by the receiver.

<u>Note</u>: *It is possible that a given receiver may use a different velocity algorithm when computing an unaugmented GPS position solution versus computing a solution augmented with differential corrections. In that case, this test must be repeated for both the augmented and unaugmented modes of operation. Even in the case where the velocity algorithm is the same whether in unaugmented or augmented mode, there are still enough variables like the software path, inputs, outputs etc., that it is required to repeat the test. However it is not required to repeat the test for different sub-modes of an unaugmented or augmented mode where the inputs, velocity algorithm and outputs are the same.*

2.5.3.4.1 Horizontal Velocity Accuracy Test Conditions

1. Ensure the simulator scenario has enough GPS satellites to provide a HDOP of 1.5 or less.
2. One satellite shall *[LAAS-375]* be set at maximum power (including maximum combined satellite and aircraft antenna gain), and the other satellites shall *[LAAS-376]* be set at minimum power (including minimum antenna gain).
3. Broadband GNSS test noise ($I_{GNSS,Test}$) of spectral density as defined in accuracy test section 2.5.3.2, broadband external interference ($I_{ext,test}$) and thermal noise contribution from the sky and the antenna ($N_{sky,antenna}$) shall *[LAAS-377]* be simulated.
4. The airborne equipment shall *[LAAS-378]* be initialized with the appropriate position and time. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting the test.

5. Platform dynamics for the horizontal velocity accuracy test shall *[LAAS-379]* be as defined in Table 2-50.

Table 2-50 Platform Dynamics For Horizontal Velocity Accuracy Test

Time (s)		**Dynamics**	**Start Jerk (g/s)**				**End Jerk (g/s)**			
From	To		North	East	Down	Total	North	East	Down	Total
0	T	Static	0	0	0	0	0	0	0	0
T+1	T+71	0.58g longitudinal acceleration to 411 m/s	0.xx *Note*	0.xx *Note*	0	0.25	0.xx *Note*	0.xx *Note*	0	0.25
T+72	T+129	Straight un-accelerated flight	0	0	0	0	0	0	0	0
T+130	T+194	-0.45g longitudinal acceleration to 125 m/s	0.xx *Note*	0.xx *Note*	0	0.2	0.xx *Note*	0.xx *Note*	0	0.2
T+195	T+254	Straight un-accelerated flight	0	0	0	0	0	0	0	0
T+255	T+325	turn 180° with 0.58g lateral acceleration	0.xx *Note*	0.xx *Note*	0	0.25	0.xx *Note*	0.xx *Note*	0	0.25
T+326	T+420	Straight un-accelerated flight	0	0	0	0	0	0	0	0

Note: *The components of the jerk in the North and East direction depend on the heading chosen in the scenario. The total jerk is the not to exceed vector combination of north, east, and down jerk components. The maximum total jerk to quickly achieve the desired dynamics should be used, but the jerk should not exceed the normal maneuver total jerk requirement of 0.25g/s.*

Note: *The actual times may vary based on the simulator scenario control settings.*

6. Signal and RF interference conditions can be modified during static period to aid acquisition. Ensure the receiver enters the desired Operation mode before dynamics and appropriate signal and interference conditions are applied.

7. *Use the simulator velocity truth data ($V_i^{east\_truth}$, $V_i^{north\_truth}$) and the GNSS receiver velocity data (V_i^{east}, V_i^{north}) to determine the horizontal velocity error h_i after the GNSS receiver has entered the desired Navigation mode with the specified signal and RF Interference conditions:*

$$h_i = \sqrt{(V_i^{east\_truth} - V_i^{east})^2 + (V_i^{north\_truth} - V_i^{north})^2} \quad .$$

2.5.3.4.1.1 Horizontal Velocity Accuracy Pass/Fail determination

The 95% Horizontal Velocity accuracy statistic shall *[LAAS-380]* be computed using the formula given below. The equipment shall *[LAAS-381]* be considered pass if the statistic is less than or equal to 10-LSB m/s.

Note: *The notation "10-LSB m/s" specifies that the pass threshold is 10 m/s minus the magnitude of the least significant bit of the output data fields representing the horizontal velocity components. The intent is to ensure that quantization error in the velocity output does not degrade the accuracy below the threshold.*

$$2 * \sqrt{\frac{\sum_{i=1}^{N}\left(\frac{1.5(h_i)}{HDOP_i}\right)^2}{N}}$$

where:

h_i - is the horizontal velocity error (m/sec)

$HDOP_i$ – Horizontal Dilution Of Precision at epoch i

N – Number of sample points used

For this test, the number of samples shall *[LAAS-382]* include all samples where the receiver is in the desired Navigation mode and when in motion.

Note: *The minimum number of samples is 420 for 1 Hz solution and 2100 for 5 Hz solution (i.e., 5* 420).*

2.5.3.4.1.2 Horizontal Velocity Figure of Merit Pass/Fail Determination

The receiver velocity data and the $HFOM_V$ data shall *[LAAS-383]* be used to determine the percentage of samples bounded by the $HFOM_V$ as shown below. The test passes if $TS_{h,b}$ is greater than or equal to 0.95.

$$TS_{h,b} = \frac{1}{N}\sum_{i=1}^{N} b_{h,i}$$

$$N = \text{number of samples}$$

$$b_{h,i} = \begin{cases} 1 & h_i \le HFOM_V \\ 0 & h_i > HFOM_V \end{cases}$$

2.5.3.4.2 Vertical Velocity Accuracy Test Conditions

1. Ensure the simulator scenario has enough GPS satellites to provide a VDOP of 3.0 or less.
2. One satellite shall *[LAAS-384]* be set at maximum power (including maximum combined satellite and aircraft antenna gain), and the other

satellites shall *[LAAS-385]* be set at minimum power (including minimum antenna gain).

3. Broadband GNSS test noise ($I_{GNSS,Test}$) of spectral density as defined in accuracy test section 2.5.3.2, broadband external interference (Iext,test) and thermal noise contribution from the sky and the antenna (Nsky,antenna) shall *[LAAS-386]* be simulated.

4. The airborne equipment shall *[LAAS-387]* be initialized with the appropriate position and time. It is assumed that the receiver has obtained a valid almanac for the simulator scenario to be tested prior to conducting the test.

5. Platform Dynamics for the vertical velocity accuracy test shall *[LAAS-388]* be as defined in Table 2-51.

Table 2-51 Platform Dynamics For Vertical Velocity Accuracy Test

Time (s)		**Dynamics**	**Start Jerk (g/s)**				**End Jerk (g/s)**			
From	To		North	East	Down	Total	North	East	Down	Total
0	T	Static	0	0	0	0	0	0	0	0
T+1	T+71	0.58g longitudinal acceleration to 411 m/s	0.xx *Note*	0.xx *Note*	0	0.25	0.xx *Note*	0.xx *Note*	0	0.25
T+72	T+130	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0
T+131	T+131+X	Climb, increasing the vertical climb rate from 0 to 21 m/s, then decrease the rate back to 0 m/s and repeat this increasing and decreasing pattern until the time out.	0	0	0.xx *Note*	0.25	0	0	0.xx *Note*	0.25
T+132+X	T+192+X	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0
T+193+X	T+193+2X	Descend, increasing the vertical descent rate from 0 to 21 m/s, then decrease the rate back to 0 m/s and repeat this increasing and decreasing pattern until the time out.	0	0	0.xx *Note*	0.25	0	0	0.xx *Note*	0.25
T+194+2X	T+274+2X	Straight and level un-accelerated flight	0	0	0	0	0	0	0	0

Note 1: The components of the jerk in the North and East direction depend on the heading chosen in the scenario. The total jerk is the not to exceed vector combination of north, east, and down jerk components. The maximum total jerk to quickly achieve the desired dynamics should be used, but the jerk should not exceed the normal maneuver total jerk requirement of 0.25g/s.

Note 2: The actual times may vary based on the simulator scenario control settings.

Note 3: The value of X must be at least 63 seconds to have enough samples during vertical acceleration.

6. Signal and RF Interference conditions can be modified during static period to aid acquisition. Ensure the receiver enters the desired Operation mode before dynamics and appropriate signal and interference conditions are applied.

7. Use the simulator velocity truth data ($V_i^{vertical\_truth}$) and the GNSS receiver velocity data ($V_i^{vertical}$) to determine the vertical velocity error (v_i) after the GNSS receiver has entered the desired Navigation mode with the specified signal and RF Interference conditions: $v_i = \left| V_i^{vertical\_truth} - V_i^{vertical} \right|$.

2.5.3.4.2.1 Vertical Velocity Accuracy Pass/Fail determination

The 95% Vertical Velocity accuracy statistic shall *[LAAS-389]* be computed using the formula given below. The equipment shall *[LAAS-390]* be considered pass if the statistic is less than or equal to 50-LSB ft/s.

$$2 * \sqrt{\frac{\sum_{i=1}^{N} \left(\frac{3(v_i)}{VDOP_i} \right)^2}{N}}$$

where:

v_i - is the vertical velocity error (ft/sec)

$VDOP_i$ – Vertical Dilution Of Precision at epoch i.

N – Number of sample points used

For this test, the number of samples shall *[LAAS-391]* include all samples where the receiver is in the desired Navigation mode.

Note: The minimum number of samples is 420 for 1 Hz solution and 2100 for 5 Hz solution.

2.5.3.4.2.2 Vertical Velocity Figure of Merit Pass/Fail Determination

The receiver velocity data and the $VFOM_V$ data shall *[LAAS-392]* be used to determine the percentage of samples bounded by the $VFOM_V$ as shown below. The test passes if $TS_{v,b}$ is greater than or equal to 0.95.

$$TS_{v,b} = \frac{1}{N}\sum_{i=1}^{N} b_{v,i}$$

$$N = \text{number of samples}$$

$$b_{v,i} = \begin{cases} 1 & v_i \le VFOM_V \\ 0 & v_i > VFOM_V \end{cases}$$

2.5.3.4.3 Optional Additional Tests To Demonstrate an Improved Level of Accuracy

The following procedure is one acceptable means for equipment capable of better accuracy performance to demonstrate compliance with the horizontal velocity error requirement of less than 3 m/s.

1. Run the scenario in Table 2-50 with all satellites set at high power and no RF interference.
2. This accuracy evaluation shall *[LAAS-405]* only include those data samples collected during the acceleration period.
3. Find the particular h_i (noted as T_{acc}) so that 95% of h_i samples are less than or equal to T_{acc}.
4. Re-run the scenario in Table 2-50 with the same satellite and RF interference conditions as the 10 m/s test.
5. This time only the data samples during the non-acceleration period with the specified signal and RF Interference conditions are used.
6. Compute $T_{non\_acc} = 2 * \sqrt{\dfrac{\sum_{i=1}^{N_{non\_acc}} \left(\dfrac{1.5(h_{i\_non\_acc})}{HDOP_{i\_non\_acc}} \right)^2}{N_{non\_acc}}}$

   where: $HDOP_{i\_non\_acc}$ and N_{non_acc} are the HDOP values for each sample i and the total number of samples (non-acceleration period), respectively.
7. The test passes only if $T_{acc} + T_{non\_acc}$ is less than or equal to 3-LSB m/s.
8. The velocity FOM is evaluated in the same way as for the 10 m/s test (i.e., the samples during acceleration and non-acceleration periods of the above 2 runs are evaluated together against the 0.95 threshold).

The vertical velocity requirement of 15 ft/s should be tested using the exact same philosophy as the test of 3 m/s above but with the scenario in Table 2-51.

3 Installed Equipment Performance Requirements

3.1 General Performance Requirement

The installed equipment shall *[LAAS-254]* meet the performance requirements of Section 2 in addition to or as adapted by this section.

3.2 Interference Effects

The equipment shall *[LAAS-255]* not be installed in such a manner as to be the source of objectionable conducted or radiated interference or to be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

Given the relatively low signal power of GPS/LAAS, special precautions may have to be taken to prevent interference. The following factors are among those that should be considered:

a) Double-shielded cabling may need to be used between the GPS/LAAS antenna and GPS/LAAS equipment.

b) The GPS/LAAS antenna should be separated as much as possible from other antennas (e.g., VHF, SATCOM, and HF in particular) and the windscreen (to prevent case-to-antenna coupling).

c) Installations involving multiple GPS/LAAS equipment may require special isolation techniques.

d) The GPS/LAAS equipment should generally be installed as far away as feasible from any VHF transmitter boxes.

e) Both DME and a faulty ELT have been known to cause interference to GPS.

3.3 Inadvertent Turnoff

There shall *[LAAS-256]* be a limited risk of inadvertent turnoff.

3.4 Test Environment

Unless otherwise specified, tests are to be conducted with the equipment installed in the aircraft type of intended use and powered by the aircraft's electrical power generating system.

3.5 Associated Equipment or Systems

Unless otherwise specified, all electrically operated aircraft equipment and systems must be operational before conducting installed interference tests.

3.6 Environmental Conditions

The equipment shall *[LAAS-258]* not be installed on aircraft in which the equipment would be subject to environmental conditions that exceed those specified by the manufacturer.

3.7 Adjustment of Equipment

Circuits of the equipment under test shall *[LAAS-259]* be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

3.8 Warm-Up Period

Unless otherwise specified, all tests shall *[LAAS-260]* be conducted after the manufacturer's specified warm-up (stabilization) period. This period shall *[LAAS-261]* not exceed 15 minutes.

3.9 GPS Antenna and Installation Requirements

Verify that the antenna is compatible with the particular type of GPS/LAAS equipment installed (e.g., that the antenna incorporates or does not incorporate a low-noise amplifier as expected by the GPS/LAAS equipment). Verify that adequate isolation is provided between the GPS/LAAS antenna and any transmitting antenna(s) installed on the aircraft (or between multiple GPS antennas). Ensure that antenna installation minimizes the effects of blockage due to the wings, tail, etc. during aircraft maneuvering. Verify that the GPS antenna is not installed just aft of the top of the windscreen (i.e., avoid case-to-antenna coupling) or in a location which may result in ice accumulation on the antenna.

Antenna installation in close proximity to traffic alert and collision avoidance system (TCAS), satellite communication (SATCOM), and other transmitting antennas (particularly "L" band) should be carefully evaluated for potential mutual interference.

3.10 VDB Aircraft Implementation Factor

The aircraft implementation factor shall [LAAS-262] be less than 6 dB and greater the –15 dB for horizontally polarized antenna, or less than 6 dB and greater than –11 dB for the vertical polarized antenna. The total implementation factor is the algebraic sum (in decibels) of the antenna gain (referenced to an isotropic radiator) and the attenuation (as a negative number) between the antenna and the VDB receiver. The attenuation includes line dissipation and VSWR mismatch losses. The implementation factor should be verified over the frequency range 108.000 to 117.975 MHz.

Note: *These aircraft implementation factors are based on the VDB link budget given in RTCA/DO-245A.*

3.11 GNSS Electromagnetic Compatibility

Verify electromagnetic compatibility between the GPS/LAAS equipment and other aircraft equipment. Particular attention should be given to other "L" band equipment, such as TCAS or SATCOM equipment; VHF transmissions on the frequencies listed below; high frequency (HF) communications systems; and other transmitting equipment (e.g., ACARS, AFIS, Flightfone, etc.).

Verification of adequate isolation from the interference of VHF communication transceivers is required. These tests shall *[LAAS-263]* be conducted on the completed GPS/LAAS installation by tuning each VHF transmitter to the frequencies listed below and transmitting for a period of 20 seconds. Degradation of individually received satellite signals below a point where navigation is no longer possible is not acceptable and will require that additional isolation measures (e.g., low pass or notch filters installed at the output of the VHF transmitter) be included in the aircraft installation. The following VHF frequencies shall *[LAAS-264]* be evaluated:

121.150 MHz	131.250 MHz
121.175 MHz	131.275 MHz
121.200 MHz	131.300 MHz

3.12 VDB Electromagnetic Compatibility

Electromagnetic compatibility between VDB equipment and other equipment shall *[LAAS-265]* be verified by a combination of compliance with design requirements, bench testing and installed performance testing.

The VDB antenna should operate such that the maximum received power from any on-board transmitter does not exceed the desensitization levels of the VDB receiver specified in Section 2.2.9.1.

Note: *Due to proximity in frequency, special care must be taken to reject transmission from any on-board VHF transmitter communication systems operating in the band 118.000 to 136.975 MHz. For horizontally polarized VDB antenna operating in the presence of a +40 dBm (EIRP) vertically polarized VHF communications transmission, at least 53 dB of isolation is required to protect the VDB receiver from desensitization. This isolation maybe achieved through a combination of 15 dB of cross-polarization rejection and 38 dB of antenna coupling. For vertically polarized VDB antenna operating in the presence of other vertically polarized transmissions, the full 53 dB of isolation must be achieved by the antenna coupling.*

3.13 Equipment Interfaces

The GPS/LAAS avionics equipment interfaces should be designed such that when properly installed with other adequately designed equipment:

a) normal or abnormal GPS/LAAS equipment operation shall *[LAAS-266]* not adversely affect the operation of the other equipment (except as specifically allowed), and

b) normal or abnormal operation of the other equipment shall *[LAAS-267]* not adversely affect the GPS/LAAS equipment (except as specifically allowed).

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4 OPERATIONAL PERFORMANCE REQUIREMENTS

4.1 Alert Presentation

Alerts can be presented in a variety of ways depending on the installed avionics equipment of a particular aircraft. Some aircraft will be equipped with Electronic Flight Instruments while others will be equipped with mechanical instrumentation and discrete indicators.

Alerts may result in the form of a mechanical flag dropping into view on a mechanical instrumented aircraft to a more sophisticated presentation on an Electronic Flight Control equipped aircraft. A common form of presentation for alerts may be used; for example, the vertical flag may be used to indicate vertical integrity alerts.

The GPS/LAAS avionics equipment interfaces must be designed such that when an aircraft on the final stage of the precision approach passes the GPIP (reference Section 2.3.11.5.1.2), the precision approach vertical guidance indication to the pilot (e.g., the vertical course deviation indicator needle) shall *[LAAS-276]* be removed or indicate full-scale fly up.

Note: *The intent of this requirement is to avoid having the pilot display indicate a fault in the SIS or airborne receiver.*

Note: *The guidance indication in this requirement refers to that indication provided to the pilot of the aircraft's position relative to the desired path. A flag or other indication of the validity or status of this guidance is not considered guidance.*

4.2 Guidance Reference Point

Deviations are defined for a guidance reference point (GRP). The GRP for lateral and vertical deviations may be different. The GRP may be the phase-center of the GPS antenna, a fixed offset (in the along-track and vertical axis), or a separate point referenced to the aircraft.

If the GRP is the phase-center of the antenna or a fixed offset, there is no additional position error resulting from this offset. However, the offset must be determined to be operationally acceptable at time of installation.

If the GRP is translated to another point on the aircraft, there is an additional error term introduced in the guidance by the input of aircraft pitch, roll and yaw. This error must be addressed at time of installation.

4.3 Missed Approach Guidance

It is required that all LAAS equipped aircraft provide missed approach guidance capability in order to support the lowest landing minimum. LAAS equipped aircraft will most likely provide this capability by integrating the LAAS equipment with a RNAV system (e.g., FMS).

For non-RNAV equipped aircraft, the LAAS equipment may sequence based on an input commanding missed approach or by automatic sequencing to missed approach guidance. The automatic sequence will occur when all of the following conditions are satisfied: 1) the aircraft position is past the LTP/FTP (i.e., when the bearing to the LTP/FTP is more than ±90 deg from the FAS bearing), 2) the aircraft altitude is greater than the touchdown zone elevation (TDZE) (or LTP/FTP altitude) plus 200 feet, and 3) the proportional vertical deviation is full-scale fly down (≥ 150 μAmps).

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Appendix A

Acronyms, Abbreviations, and Definitions

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A Acronyms, Abbreviations, and Definitions

A.1 Acronyms and Abbreviations

σ - (Sigma) Standard deviation of a normally distributed random variable

A - Analysis

A/D - Analog to Digital

AAD - Airborne Accuracy Designator

ABAS - Aircraft Based Augmentation System

AC - Advisory Circular

AEC - Airborne Equipment Classification

AFC - Automatic Frequency Control

AGC - Automatic Gain Control

ARP - Aerospace Recommended Practice

AST - Approach Service Type

ATC - Air Traffic Control

AWGN - Additive White Gaussian Noise

BAM - Bias Approach Monitor

BW - Bandwidth

CAT I - Category I Precision Approach

CCIR - Consultative Committee International Radio

CDI - Course Deviation Indicator

CRC - Cyclic Redundancy Check

CW - Continuous Wave (CW) or Course Width (CW)

CWI - Continuous Wave Interference

D - Demonstration

DA - Decision Altitude

D/U - Desired-to-Undesired (signal ratio)

D8PSK - Differential 8-Phase Shift Keying

DD - Double Delta

DDM - Difference in Depth of Modulation

DLL - Delay Lock Loop

Dmax - Maximum Use Distance

DO - Document

DP - Decision Point

ECEF	-	Earth Centered Earth Fixed
EMI	-	Electromagnetic Interference
FAA	-	U.S. Federal Aviation Administration
FAF	-	Final Approach Fix
FANS	-	Future Air Navigation System
FAR	-	Federal Aviation Regulations
FAS	-	Final Approach Segment
FASLAL	-	Final Approach Segment Lateral Alert Limit
FASVAL	-	Final Approach Segment Vertical Alert Limit
FD	-	Fault Detection
FEC	-	Forward Error Correction
FM	-	Frequency Modulation
FMS	-	Flight Management System
FOM	-	Figure of Merit
FPAP	-	Flight Path Alignment Point
FSD	-	Full-Scale Deflection
ft	-	feet
FTE	-	Flight Technical Error
FTP	-	Fictitious Threshold Point
g	-	Acceleration of gravity
GARP	-	GLS Azimuth Reference Point
GAST	-	GBAS Approach Service Type
GBAS	-	Ground-Based Augmentation System
GBRS	-	Ground-Based Ranging Source
GCID	-	Ground Continuity and Integrity Designator
GERP	-	GLS Elevation Reference Point
GFC	-	Ground Facility Classification
GLONASS	-	Global Orbiting Navigation Satellite System
GLS	-	GNSS Landing System
GNSS	-	Global Navigation Satellite System
GPA	-	Glide Path Angle
GPIP	-	Glide Path Intercept Point
GPS	-	Global Positioning System
GRP	-	Guidance Reference Point (for aircraft guidance)
HAT	-	Height Above Threshold (actually height above LTP/FTP)

HFOM$_P$ - Horizontal Position Figure of Merit

HFOM$_V$ - Horizontal Velocity Figure of Merit

HIL - Horizontal Integrity Limit

Hpol - Horizontally Polarized (antenna)

HPL - Horizontal Protection Level

I - Inspection

I/Q - In Phase/Quadrature Phase

I/S - Interference-to-Signal

IAWP - Initial Approach Waypoint

ICAO - International Civil Aviation Organization

ICD - Interface Control Document

IF - Intermediate Frequency

ILS - Instrument Landing System

IOD - Issue of Data

IRU - Inertial Reference Unit

ITU - International Telecommunication Union

kts - Knots

LAAS - Local Area Augmentation System

LAL - Lateral Alert Limit

LGF - LAAS Ground Facility

LOC - Localizer

LPL - Lateral Protection Level

LSB - Least Significant Bit

LTP - Landing Threshold Point

MASPS - Minimum Aviation System Performance Standards

MAWP - Missed Approach Waypoint

MBI - Message Block Identifier

MFR - Message Failure Rate

MI - Misleading Information

MLS - Microwave Landing System

MOPS - Minimum Operational Performance Standards

MSB - Most Significant Bit

NIS - Number of Independent Samples

nmi - Nautical Mile

NM - Nautical Mile

NUC	-	Navigation Uncertainty Category
NUC_r	-	Navigation Uncertainty Category for Rate
PAN	-	Precision And Navigation
PAR	-	Precision Approach Region
pdf	-	Probability Density Function
PMC	-	Program Management Committee
PPM	-	Parts Per Million
PRN	-	Pseudorandom Number
PT	-	Performance Type
PVT	-	Position, Velocity and Time
QZSS	-	Quasi Zenith Satellite System
RF	-	Radio Frequency
RMS	-	Root-Mean-Squared
RNAV	-	Area/Random Navigation
RNP	-	Required Navigation Performance
RPDS	-	Reference Path Data Selector
RPI	-	Reference Path Identifier
RRC	-	Range Rate Correction
RSS	-	Root Sum of Squares
SA	-	Selective Availability
SAE	-	Society of Automotive Engineers
SARPs	-	Standards and Recommended Practices
SATCOM	-	Satellite Communication
SBAS	-	Satellite-Based Augmentation System
SC	-	Special Committee
SGD	-	Slot Group Definition
SIS	-	Signal in Space
SPS	-	Standard Positioning Service
SSID	-	Station Slot Identifier
STP	-	Surveillance Transmit Processing
T	-	Test
TBD	-	To Be Determined
TC	-	Tropospheric Correction
TCAS	-	Traffic alert and Collision Avoidance System
TCH	-	Threshold Crossing Height

TCP - Threshold Crossing Point

TDMA - Time Division Multiple Access

TDZE - Touchdown Zone Elevation

TSO - Technical Standard Order

U.S. - United States

VAL - Vertical Alert Limit

VDB - VHF Data Broadcast

$VFOM_P$ - Vertical Position Figure of Merit

$VFOM_V$ - Vertical Velocity Figure of Merit

VHF - Very High Frequency

VOR - VHF Omnidirectional Range

VPL - Vertical Protection Level

Vpol - Vertically Polarized (antenna)

VSWR - Voltage Standing Wave Ratio

VTF - Vector to Final Approach

WAAS - Wide Area Augmentation System

WGS - World Geodetic System

A.2 Definitions

Fictitious Threshold Point (FTP) – The FTP is a point functionally equivalent to a Landing Threshold Point, except that the FTP is not coincident with the designated runway threshold.

Final Approach Segment (FAS) – The straight line segment that prescribes the three-dimensional geometric path in space that an aircraft is supposed to fly on final approach.

Flight Path Alignment Point (FPAP) – The FPAP is used in conjunction with the LTP/FTP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach, landing and flight path. The FPAP may be the LTP/FTP for the reciprocal runway.

Geometric Altitude – Height above the local earth surface.

Glide Path Angle (GPA) – The glide path angle is an angle, defined at a calculated point located directly above the LTP/FTP, that establishes the intended descent gradient for the final approach flight path of a precision approach procedure. It is measured from the plane containing the LTP/FTP that is parallel to the surface of WGS-84 ellipsoid.

Global Navigation Satellite System (GNSS) – GNSS is a world-wide position, velocity, and time determination system, that includes one or more constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

Global Positioning System (GPS) – The satellite-based navigation system operated by the United States.

Glide Path Intercept Point (GPIP) – The GPIP is the point at which the extension of the final approach segment intercepts the plane containing the LTP/FTP that is parallel to the surface of WGS-84 ellipsoid.

H_0 Hypothesis – The H_0 hypothesis assumes the situation where no faults are present in the range measurements (includes both the signal and the receiver measurements) used in the ground station to compute the differential corrections.

H_1 Hypothesis – The H_1 hypothesis assumes the situation when a fault is present in one or more range measurement and is caused by one of the reference receivers used in the ground station.

Height Above Threshold (HAT) – Specifically, the height above the LTP/FTP. In using this term for airborne equipment specifications, care should be taken to define the point on the aircraft (e.g., GPS antenna, wheel height, or center of mass) that applies.

Landing Threshold Point (LTP) – The LTP is used in conjunction with the FPAP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach flight path to touchdown and rollout. It is a point at the designated center of the landing runway defined by latitude, longitude, ellipsoidal height, and orthometric height. The LTP is a surveyed reference point used to connect the approach flight path with the runway. The LTP may not be coincident with the designated runway threshold.

Mask Angle – A fixed elevation angle referenced to the user's East-North plane (local level plane) below which satellites are ignored when determining the user's position.

Maximum Use Distance (Dmax) – The maximum usable distance (slant range) from the GBAS reference point for which the differentially corrected positioning service (DCPS) performance is assured.

Misleading Information – Within this standard, misleading information is defined to be any data which is output to other equipment or displayed to the pilot that has an error larger the current protection levels (HPL, LPL/VPL) for the current operation. This includes all output data, such as position and deviations.

Non-Precision Approach – A standard instrument approach procedure in which no glideslope/glide path is provided. (Source: FAA document 7110.65G).

Precision Approach – A standard instrument approach procedure in which a glideslope/glide path is provided. (Source: FAA document 7110.65G).

Pseudorange – The distance from the user to a ranging source plus an unknown user clock offset distance. With four ranging source signals it is possible to compute position and offset distance. If the user clock offset is known, three ranging source signals would suffice to compute a position.

Reference Receiver – A subsystem of the Ground Subsystem that is used to make pseudorange measurements and may contain more than one receiver.

Satellite-Based Augmentation System (SBAS) – A differential GNSS employing satellite transponders to broadcast additional ranging signals and differential corrections usable over an extensive geographical area for the supported phases of operation.

Selective Availability (SA) – A set of techniques for denying the full accuracy and selecting the level of positioning, velocity, and time accuracy of GPS available to users of the Standard Positioning Service (L1 frequency) signal.

Standard Positioning Service (SPS) – The standard specified level of positioning, velocity and timing accuracy that is available, without qualifications or restrictions, to any user on a continuous worldwide basis.

Terminal Area – A general term used to describe airspace in which approach control service or airport traffic control service is provided.

Wide Area Augmentation System (WAAS) – The SBAS operated by the U.S. FAA.

World Geodetic System (WGS) – A set of parameters describing the size and shape of the earth, the positions of a network of points with respect to the center of mass of the earth, transformations from major geodetic datum, and the potential of the earth.

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Appendix B

Requirements Changes Between Versions

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B Requirements Evolution

This informative appendix identifies how the LAAS requirements have changed between DO-253 and DO-253A, between DO-253A and DO-253B, as well as between DO-253B and DO-253C. The tables identify a LAAS requirement as "unchanged" if it is technically the same in the updated version as it was in the previous, "editorially changed" if the requirement has had an editorial clarification, "deleted" if the requirement has been removed, and "new" if this requirement did not appear in the previous version.

B.1 Requirements Changes Between DO-253 and DO-253A

This section identifies how the LAAS requirements have changed between DO-253 and DO-253A. In addition as is indicated in the table, DO-253A has eliminated duplicate LAAS requirement designators that appeared in DO-253 and replaced them with new designators.

Table B-1 LAAS Requirements Changes Between DO-253 and DO-253A

LAAS Requirement Designator [LAAS-xxx]	DO-253A Change Status from DO-253
001-015	Unchanged
016	Editorially changed
017-041	Unchanged
042	Changed
043-044	Deleted
045-047	Unchanged
048-050	Deleted
051-060	Changed
061-067	Unchanged
068-069	Changed
070	Unchanged
071-074	Changed
075-076	Unchanged
077	Editorially changed
078-089	Unchanged
090	Editorially changed
091	Changed
092	Unchanged
093	Changed
094	Editorially changed
095-096	Unchanged
097	Editorially changed
098	Unchanged
099	Changed
100-101	Unchanged
102	Editorially changed
103-112	Unchanged
113	Editorially changed
114-115	Changed
116	Unchanged

LAAS Requirement Designator [LAAS-xxx]	DO-253A Change Status from DO-253
117	Changed
118	Unchanged
119	Deleted
120	Changed
121-122	Unchanged
123-127	Changed
128	Unchanged
129-130	Editorially changed
131	Changed
132	Unchanged
133	Changed
134	Unchanged
135	Editorially changed
136 (DO-253 Section 2.3.9.1.4)	Unchanged
136 (DO-253 Section 2.3.12)	Editorially changed. Repeated designator replaced with [141].
137 (DO-253 Section 2.3.9.1.4)	Unchanged
137 (DO-253 Section 2.3.12.1)	Editorially changed. Repeated designator replaced with [283].
138 (DO-253 Section 2.3.9.1.4)	Changed
138 (DO-253 Section 2.3.12.1)	Editorially changed. Repeated designator replaced with [284].
139 (DO-253 Section 2.3.9.1.4)	Changed
139 (DO-253 Section 2.3.12.1)	Editorially changed. Repeated designator replaced with [285].
140	Editorially changed
141	Deleted because it was redundant with the second [136]. Freed designator number was used to replace the second [136].
142	Unchanged
143	Changed
144	Unchanged
145	Changed
146	Changed
147	Deleted
148	Changed
149-150	Editorially changed
151 (DO-253 Section 2.3.11.3)	Editorially changed
151 (DO-253 Section 2.3.12.4.1)	Unchanged. Repeated designator replaced with [286].
152-153	Unchanged
154	Editorially changed
155	Changed
156	Deleted
157	Changed
158-162	Unchanged
163	Editorially changed

LAAS Requirement Designator [LAAS-xxx]	DO-253A Change Status from DO-253
164	Unchanged
165	Changed
166	Editorially changed
167-168	Unchanged
169-171	Changed
172	Unchanged
173-174	Editorially changed
175-177	Changed
178-180	Changed
181	Editorially changed
182-183	Unchanged
184	Editorially changed
185-188	Unchanged
189	Changed
190	Unchanged
191	Changed
192	Deleted
193-216	Unchanged
217 (DO-253 Section 2.5.1.6)	Unchanged. Repeated designator replaced with [289].
217 (DO-253 Section 2.5.3.1.1)	Unchanged
218-219	Unchanged
220	Changed
221	Unchanged
222	Changed
223-225	Unchanged
226	Editorially changed
227-256	Unchanged
257	Deleted
258-268	Unchanged
269-270	New
271	Unchanged
272-282	New
283	This designator replaced the second occurrence of [137].
284	This designator replaced the second occurrence of [138].
285	This designator replaced the second occurrence of [139].
286	This designator replaced the second occurrence of [151].
287-288	New
289	This designator replaced the first occurrence of [217].
290-292	New

B.2 Requirements Changes Between DO-253A and DO-253B

This section identifies how the LAAS requirements have changed between DO-253A and DO-253B.

Table B-2 LAAS Requirements Changes Between DO-253A and DO-253B

LAAS Requirement Designator [LAAS-xxx]	DO-253B Change Status from DO-253A
001-076	Unchanged
077	Changed
078-083	Deleted
084	Changed
085	Editorially changed
086	Unchanged
087	Editorially changed
088	Editorially changed
089-090	Unchanged
091	Changed
092	Unchanged
093	Changed
094-096	Unchanged
097	Editorially changed
098	Changed
099	Deleted
100	Unchanged
101-102	Changed
103-149	Unchanged
150	Changed
151-175	Unchanged
176	Changed
177	Unchanged
178	Editorially changed
179-185	Unchanged
186-191	Changed
192	Unchanged
193	Changed
195-211	Unchanged
212-214	Changed
215-218	Deleted
219	Unchanged
220	Changed
221	Deleted
224	Changed
225	Unchanged
226-227	Changed
228	Deleted
229	Unchanged
230	Editorially changed
231-238	Unchanged
239-240	Editorially changed
241-242	Unchanged

LAAS Requirement Designator [LAAS-xxx]	DO-253B Change Status from DO-253A
243-244	Editorially changed
245-248	Unchanged
249-251	Editorially changed
252-276	Unchanged
277-287	Unchanged
288	Changed
289-291	Unchanged
292	Changed
293-317	New

B.3 Requirements Changes Between DO-253B and DO-253C

This section identifies how the LAAS requirements have changed between DO-253B and DO-253C.

Table B-3 LAAS Requirements Changes Between DO-253B and DO-253C

LAAS Requirement Designator [LAAS-xxx]	DO-253C Change Status from DO-253B
001-031	Unchanged
032	Editorially changed
033-067	Unchanged
068-069	Changed
070-076	Unchanged
077	Editorially changed
078-084	Unchanged
085	Editorially changed
086-088	Unchanged
089	Editorially changed
090	Unchanged
091	Editorially changed
092	Unchanged
093	Changed
094-101	Unchanged
097	Changed
098-100	Unchanged
101	Editorially changed
102-106	Unchanged
107	Editorially changed
108-109	Unchanged
110	Editorially changed
111-112	Unchanged
113-114	Editorially changed
115-116	Unchanged
117	Editorially changed
118-119	Unchanged
120	Editorially changed
121-122	Unchanged

LAAS Requirement Designator [LAAS-xxx]	**DO-253C Change Status from DO-253B**
124	Editorially changed
125-129	Unchanged
130	Editorially changed
131-132	Changed
133-134	Editorially changed
135	Unchanged
136	Editorially changed
137	Unchanged
138	Editorially changed
139-168	Unchanged
169-170	Editorially changed
171-178	Unchanged
179-181	Changed
182-273	Unchanged
274	Editorially changed
275-277	Unchanged
278-279	Changed
280	Unchanged
281	Deleted
282	Editorially changed
283-286	Unchanged
287-288	Changed
288	Editorially changed
289-303	Unchanged
304	Changed
305-312	Unchanged
313	Changed
314-315	Unchanged
316	Changed
317	Editorially changed
318-406	New

Note: *DO-253C contains LAAS requirements designators numbered in the range from 001 to 405. The following LAAS requirements designator numbers have been deleted during the evolution from DO-253 to DO-253C: 043-044, 048-050, 078-083, 099, 119, 147, 156, 192, 215-218, 221, 228, 257, and 281.*

Appendix C

Final Approach Segment and Deviation Example

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C Final Approach Segment and Deviation Example

C.1 Introduction

This informative appendix describes the Final Approach Segment (FAS) data and how this data defines the FAS. This appendix also discusses the computation and scaling of deviation outputs.

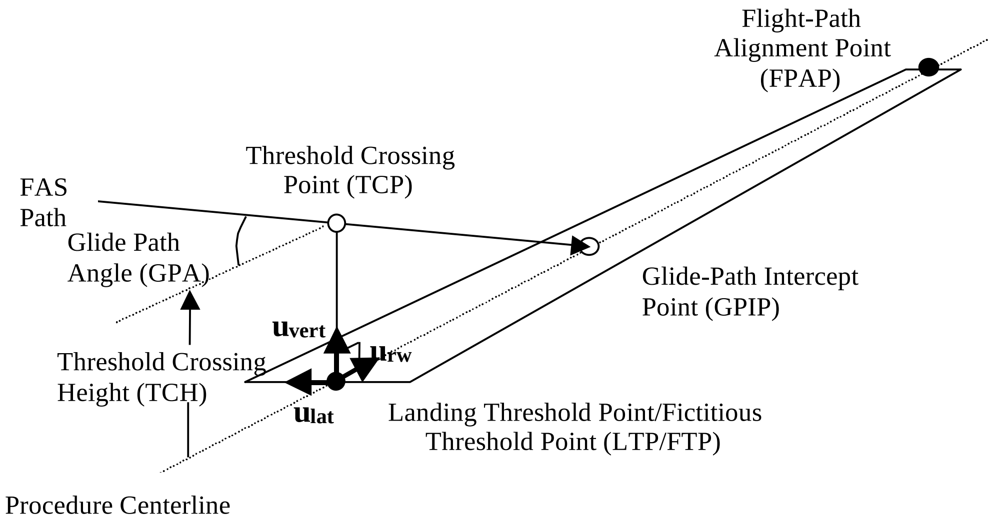
C.2 Final Approach Segment (FAS)

C.2.1 FAS Definition

The Final Approach Segment (FAS) is defined using a set of FAS definition parameters identified in Table C-1 and illustrated in Figure C-1.

Table C-1 The FAS Definition Parameters

Data	Definition
Landing Threshold Point/Fictitious Threshold Point (LTP/FTP)	Latitude (WGS-84 -Geodetic) Longitude (WGS-84 - Geodetic) Height above WGS-84 ellipsoid
Flight Path Alignment Point (FPAP) Offset from the LTP/FTP	Delta Latitude (WGS-84) Delta Longitude (WGS-84)
Threshold Crossing Height (TCH)	Desired height of the FAS at the LTP/FTP
Glide Path Angle (GPA)	Angle between the glide path and the local level plane at the LTP/FTP
Course Width (CW)	Lateral displacement at the LTP/FTP resulting in full-scale deflection sensitivity)
ΔLength Offset	Along-Track offset of the end of the runway from the FPAP



Note: The FPAP is below the local level plane containing the LTP/FTP. Refer to Figure 2-6.

Figure C-1 Final Approach Segment Definition

Local vertical for the approach is defined as normal to the WGS-84 ellipsoid at the LTP/FTP. The local level plane for the approach is defined as a plane perpendicular to the local vertical passing through the LTP/FTP. The Threshold Crossing Point (TCP) is a point at a height defined by the Threshold Crossing Height (TCH) above the LTP/FTP. The vertical plane (or Lateral Deviation Reference Plane) is defined as a plane containing the LTP/FTP, the TCP, and the Flight Path Alignment Point (FPAP). The final approach path is defined as a line in the vertical plane passing through the TCP with an angle (defined by the Glide Path Angle or GPA) relative to the local level plane. The Glide Path Intercept Point (GPIP) is the point where the final approach path intercepts the local level plane. The GPIP may actually be above or below the runway surface depending on the curvature of the runway.

C.2.2 Example Calculation of FAS Unit Vectors

The derived FAS unit vectors should be computed in a manner consistent with the relationships described in Section C.2.1. One acceptable means of computing the derived FAS unit vectors is as follows:

Define $\mathbf{r}_{LTP/FTP}^{ECEF}$ to be the vector from the center of the earth to the LTP/FTP expressed in WGS-84 ECEF Cartesian coordinates. Define $\mathbf{r}_{TCP}^{ECEF}$ to be the vector from the center of the earth to the TCP in ECEF Cartesian coordinates. The vertical unit vector ($\mathbf{u}_{vert}$) which is defined to be the normal to the WGS-84 ellipsoid at the LTP/FTP is computed:

$$\mathbf{u}_{\text{vert}} = \frac{(\mathbf{r}_{\text{TCP}}^{\text{ECEF}} - \mathbf{r}_{\text{LTP / FTP}}^{\text{ECEF}})}{\text{TCH}}$$

Define $\mathbf{r}_{FPAP}^{ECEF}$ be a vector from the center of the earth to the FPAP in WGS-84 ECEF Cartesian coordinates using the ellipsoidal height of the LTP/FTP.

To define the along-track and cross-track unit vectors, a flight path alignment unit vector that points from the LTP/FTP to the FPAP is computed:

$$\mathrm{u}_{FPA}^{ECEF} = \frac{\mathrm{r}_{FPAP}^{ECEF} - \mathrm{r}_{LTP\,/\,FTP}^{ECEF}}{\left\| \mathrm{r}_{FPAP}^{ECEF} - \mathrm{r}_{LTP\,/\,FTP}^{ECEF} \right\|}$$

The unit vector in the lateral direction (positive as shown) is computed using a vector cross-product:

$$\mathbf{u}_{lat} = \frac{\mathbf{u}_{vert} \times \mathbf{u}_{FPA}}{\left\| \mathbf{u}_{vert} \times \mathbf{u}_{FPA} \right\|}$$

The unit vector in the longitudinal (or runway (rw) frame) direction is computed:

$$\mathbf{u}_{rw} = \mathbf{u}_{lat} \times \mathbf{u}_{vert}$$

The procedure centerline passes through the LTP/FTP and is aligned with u_{rw}. The local level plane is the plane containing $\mathbf{u}_{lat}$ and $\mathbf{u}_{rw}$. The lateral deviation reference plane is the plane containing $\mathbf{u}_{vert}$ and $\mathbf{u}_{rw}$. Unit vectors are shown in Figure C-1.

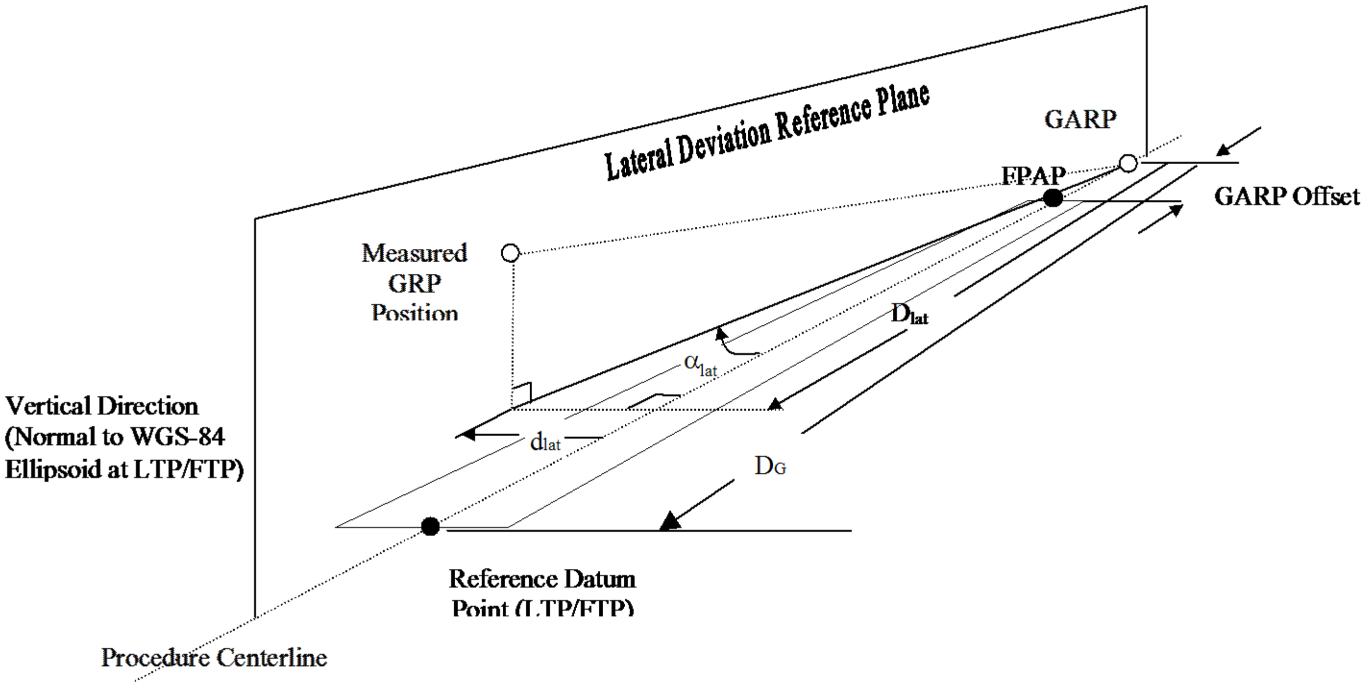
C.3 Deviation Computations

The LAAS airborne equipment outputs guidance information in the form of deviations relative to a desired flight path defined by the FAS.

C.3.1 Lateral Deviations

C.3.1.1 Lateral Deviation Definition

The rectilinear lateral deviation (d_{lat} in Figure C-2) is the distance of the measured airplane GRP position from the lateral deviation reference plane (positive as shown). The angular lateral deviation is a corresponding angular displacement stated with respect to the GLS Azimuth Reference Point (GARP). The GARP is defined to be on the procedure centerline 305 m beyond the point where the vertical projection of the FPAP intersects with the procedure centerline. The angular lateral deviation (α_{lat} in Figure C-2) is the angle whose tangent is the ratio of d_{lat} and the horizontal distance from the GRP to the GARP (D_{lat} in Figure C-2).



Note: The FPAP is below the local level plane containing the LTP/FTP. Refer to Figure 2-6.

Figure C-2 LATERAL DEVIATIONS

The angular lateral deviation output is expressed in terms of Difference in Depth of Modulation (DDM), which is determined via:

$$Lateral\_DDM = \frac{0.155}{\tan^{-1}\left(\frac{CourseWidth}{D_G}\right)} \bullet \alpha_{lat}$$

where: D_G = distance from the GARP to the LTP/FTP.

The Course Width is provided in the FAS data block.

C.3.1.2 Lateral Deviation Example Calculations

One acceptable means of computing the lateral deviations is as follows:

Define $\mathbf{r}_{\mathrm{GARP}}^{\mathrm{ECEF}}$ to be the vector from the center of the earth to the GARP in ECEF Cartesian coordinates:

$$\mathbf{r}_{GARP}^{ECEF} = \mathbf{r}_{FPAP}^{ECEF} + D_{GARP}\mathbf{u}_{rw}$$

where D_{GARP} is the GARP offset. *(Note: Although this formulation defines a GARP that is below the actual GARP, it will not affect the value of the calculated deviation.)* Define $\mathbf{r}_{GRP}^{ECEF}$ to be the vector from the center of the earth to the computed airplane Guidance Reference Point (GRP) expressed in WGS-84 ECEF Cartesian coordinates. The rectilinear lateral deviation is computed:

$$d_{lat} = \mathbf{u}_{lat} \cdot (\mathbf{r}_{GRP}^{ECEF} - \mathbf{r}_{GARP}^{ECEF})$$

The angular lateral deviation, α_{lat}, is computed:

$$\alpha_{lat} = \tan^{-1}\left\{ \frac{d_{lat}}{\left| \mathbf{u}_{rw} \cdot (\mathbf{r}_{GRP}^{ECEF} - \mathbf{r}_{GARP}^{ECEF}) \right|} \right\}$$

C.3.2 Vertical Deviations

C.3.2.1 Vertical Deviation Definition

The vertical deviations are stated with respect to a GLS Elevation Reference Point (GERP) as illustrated in Figure C-3. The GERP may be at the GPIP or laterally offset from the GPIP by a fixed GERP Offset value of 150 m.

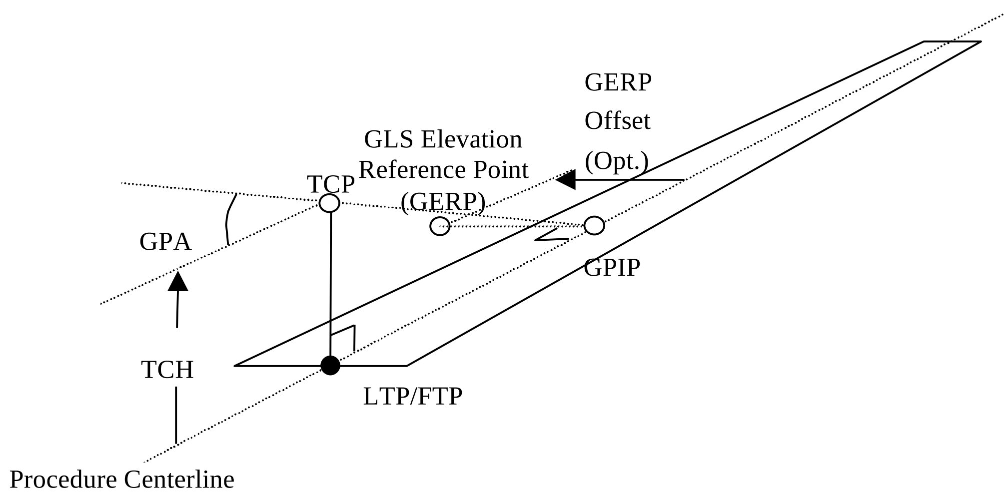


Figure C-3 GLS Elevation Reference Point Definition

The rectilinear vertical deviation (d_v in Figure C-4) is the distance of the measured airplane GRP from the surface of a vertically-oriented, circular cone with its apex at the GERP and with an angle defined by GPA (positive as shown). The angular vertical deviation (α_v in Figure C-4) is the angle whose sine is the ratio of the rectilinear vertical deviation and the distance from the aircraft to the GERP (D_v in Figure C-4).

Note: *The definition for "Dv" that is used in this appendix is not the same as the definition for "Dv" that is used in the body of this MOPS.*

The angular vertical deviation is expressed in terms of DDM, with scaling via:

$$Vertical\ DDM = \frac{0.175 \cdot \alpha_v}{0.25 \cdot GPA}$$

Note: The width is consistent with Annex 10 MLS characteristics, which are slightly inconsistent with Annex 10 ILS characteristics.

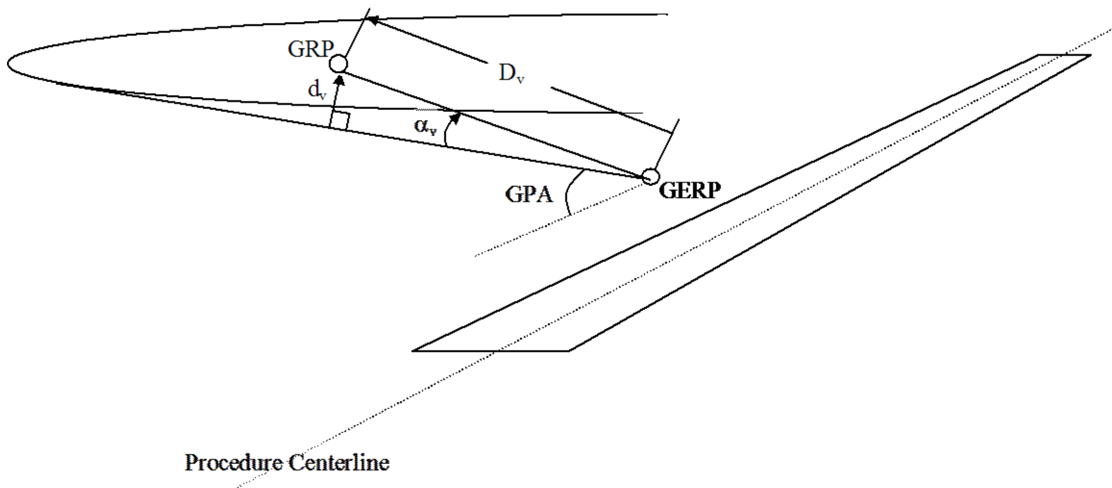


Figure C-4 GLS Vertical Deviation Definition

C.3.2.2 Vertical Deviation Example Calculations

The vertical deviations should be computed in a manner consistent with the definitions in Section C.3.2.1 above. One acceptable means of computing the vertical deviations is as follows.

The GERP position can be computed by:

$$\mathbf{r}_{\mathrm{GERP}}^{\mathrm{ECEF}} = \mathbf{r}_{\mathrm{LTP/FTP}}^{\mathrm{ECEF}} + \frac{\mathrm{TCH}}{\tan(\mathrm{GPA})}\mathbf{u}_{\mathrm{rw}} + \mathrm{D}_{\mathrm{GERP}}\mathbf{u}_{\mathrm{lat}}$$

where D_{GERP} is the GERP offset of 150 m. The angular vertical deviation is computed:

$$\alpha_{\mathrm{v}} = \tan^{-1}\left\{\frac{\left[\mathbf{u}_{\mathrm{vert}} \cdot (\mathbf{r}_{\mathrm{GRP}}^{\mathrm{ECEF}} - \mathbf{r}_{\mathrm{GERP}}^{\mathrm{ECEF}})\right]}{\sqrt{\left[\mathbf{u}_{\mathrm{lat}} \cdot (\mathbf{r}_{\mathrm{GRP}}^{\mathrm{ECEF}} - \mathbf{r}_{\mathrm{GERP}}^{\mathrm{ECEF}})\right]^2 + \left[\mathbf{u}_{\mathrm{rw}} \cdot (\mathbf{r}_{\mathrm{GRP}}^{\mathrm{ECEF}} - \mathbf{r}_{\mathrm{GERP}}^{\mathrm{ECEF}})\right]^2}}\right\} - \mathrm{GPA}$$

The rectilinear vertical deviation is computed:

$$d_v = \sin(\alpha_v)\left\|\mathbf{r}_{GRP}^{ECEF} - \mathbf{r}_{GERP}^{ECEF}\right\|$$

Appendix D

Standard GPS Interference Environment

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D Standard GPS Interference Environment

D.1 Introduction

This normative appendix specifies the RF interference environment, at and around L-band frequencies, for GPS/LAAS airborne receivers. It also describes the frequency selectivity of the minimum standard antenna.

All signal levels in this appendix are specified in dBm measured at the antenna port.

D.2 Operating Interference Environment

Interference levels specified in this appendix are defined at the antenna port regardless of antenna radiation pattern.

Figure D-1 represents the operating interference environment. The regions of this figure indicated as having interference with bandwidths other than CW are considered to represent in-band and near-band interference with received power levels defined in Figure D-2 as a function of bandwidth. Figure D-3 represents the frequency selectivity of the minimum standard antenna in order to define the operating environment of equipment using such an antenna.

D.2.1 Out-of-Band Interference

The out-of-band continuous wave (CW) interfering signals can be as high as the levels shown in Figure D-1, measured at the antenna port. The CW interference level below 1500 MHz increases linearly to 25.5 dBm at 1315 MHz. The CW level increases linearly above 1640 MHz to 21.5 dBm at 2 GHz, accounting for High Intensity Radiation Fields (HIRF).

D.2.1.1 Out-of-Band Pulse Interference

After steady state navigation has been established, the equipment could receive pulsed interference in the out-of-band frequency ranges specified above having the characteristics described in Table D-1.

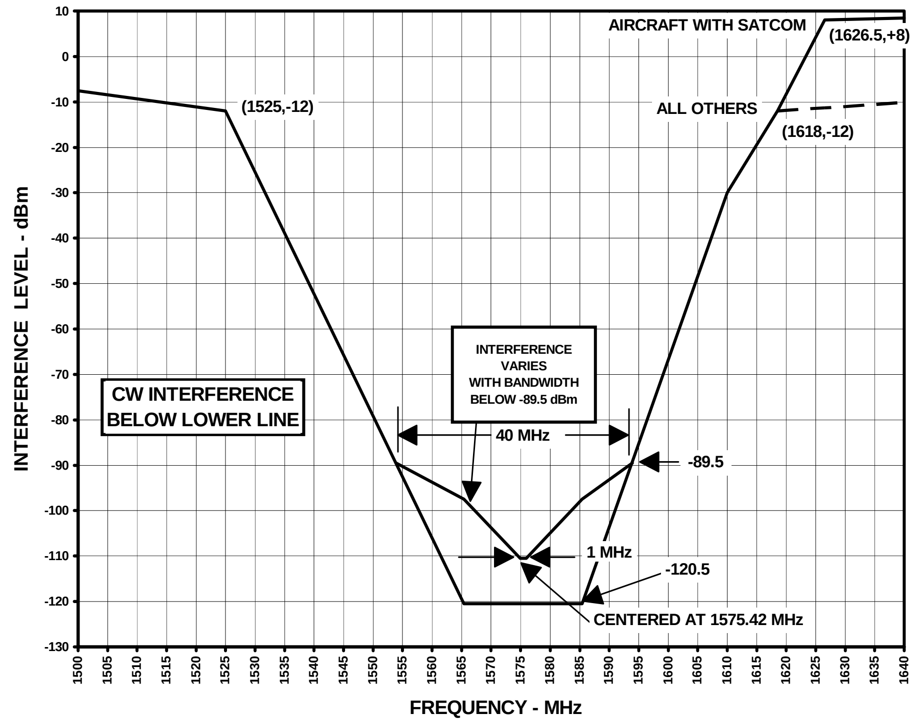

Figure D-1 Interference Levels at the Antenna Port

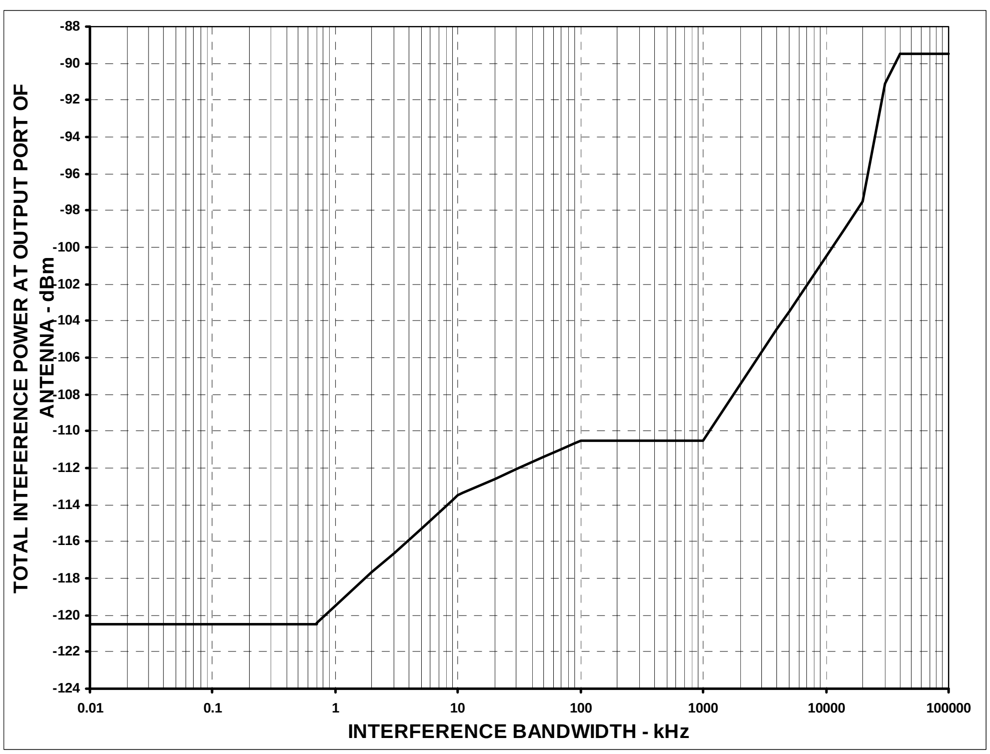

Figure D-2 In-Band and Near-Band Interference Environments

Table D-1 Out-Of-Band Pulse Interference

	GPS/SBAS
Peak Power	+30 dBm
Pulse Width	125 μsec
Pulse Duty Cycle	1%

D.2.2 In-Band and Near-Band Interference

Figure D-1 and Figure D-2 are related as follows: The upper mask of Figure D-1 (the mask that varies with bandwidth) at 1575.42 MHz ±0.5 MHz relates to the level in Figure D-2 between the bandwidths of 100 and 1000 kHz. For interference bandwidths outside of that range, the level of the mask in Figure D-1 is adjusted up or down according to the levels of Figure D-2. For example, interference with a bandwidth of 0.1 kHz lowers the mask to the CW interference mask at 1575.42 MHz to a level of –120.5 dBm, while interference with bandwidth of 20 MHz raises the mask at 1575.42 MHz to a level of -97.5 dBm. In addition, if the center of the interference moves away from 1575.42 MHz, the levels of Figure D-2 for bandwidths not greater than 20 MHz are raised according to the mask of Figure D-1. For example, for interference centered at 1565.42 MHz, the curve of Figure D-2 is increased by 13 dB.

The baseline in-band and near-band interference environments apply to all precision approach operations. In this section, the bandwidth of the interferor is given in terms of the 3 dB bandwidth of the interferor.

After steady state navigation has been established, the equipment could receive an interfering signal in the frequency range of $1575.42 \pm BW_I/2$ MHz that is as high as the levels in Table D-2 which are given as a function of the interfering signal bandwidth BW_I.

For terminal area steady-state navigation operations and for the initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the in-band and near-band interference levels are 6 dB less than those for precision approach defined above.

Table D-2 In-Band And Near-Band Interference Bandwidth Definitions

BANDWIDTH	INTERFERENCE LEVEL
$0 \leq BW_I \leq 700$ Hz	-120.5 dBm
700 Hz < $BW_I \leq 10$ kHz	Linearly increasing from -120.5 dBm to -113.5 dBm [Note 1]
10 kHz < $BW_I \leq 100$ kHz	Linearly increasing from -113.5 dBm to -110.5 dBm [Note 1]
100 kHz < $BW_I \leq 1$ MHz	-110.5 dBm
1 MHz < $BW_I \leq 20$ MHz	Linearly increasing [Note 1] from -110.5 to -97.5 dBm [Note 2]
20 MHz < $BW_I \leq 30$ MHz	Linearly increasing [Note 1] from -97.5 to -91.1 dBm [Note 2]
30 MHz < $BW_I \leq 40$ MHz	Linearly increasing [Note 1] from -91.1 to -89.5 dBm [Note 2]
40 MHz < BW_I	-89.5 dBm [Note 2]

[1] Increase in interference power is linear for the units shown in Table D-2.

[2] Interference levels will not exceed –110.5 dBm/MHz in the frequency range of 1575.42 ± 10 MHz.

These interfering levels as a function of bandwidth are shown in Figure D-2.

D.2.2.1 In-Band and Near-Band Pulsed Interference

After steady state navigation has been established, the equipment operating in all flight phases could receive pulsed interference in the in-band and near-band frequency ranges specified above having the characteristics described in Table D-3.

Table D-3 In-Band And Near-Band Pulse Interference

	GPS/SBAS
Peak Power	+10 dBm
Pulse Width	125 μsec
Pulse Duty Cycle	1%
Signal Bandwidth	1 MHz

D.2.3 GNSS Noise

The GNSS Noise is a broadband noise with spectral density that has an equivalent effect on the equipment as the aggregate power from the anticipated future GNSS environment, including GPS C/A, P/Y, and M-code signals from a full GPS constellation, SBAS C/A code signals from the anticipated SBAS providers, QZSS and Galileo. Values are specified in Table D-4 for different receiver functions due to different signal coupling and operational requirements.

Table D-4 Effective Noise Density for All GNSS Sources

Receiver Function	Effective Noise Density (dBm/Hz)
Initial Acquisition (GPS Only)*	-172.2
GPS Tracking and Re-acquisition	-171.9
SBAS Tracking and Re-acquisition	-172.8

* In the presence of many GPS signals, it is assumed that the receiver will acquire GPS satellites first so that an SBAS signal is not necessary for initial acquisition.

D.3 Minimum Standard Antenna Frequency Selectivity

When received by a minimum standard antenna, interfering signals are attenuated, at minimum, in accordance with the frequency selectivity shown in Table D-5 and Figure D-3.

Table D-5 Frequency Selectivity

Frequency (MHz)	Selectivity (dB)
$1315 \leq f < 1504.42$	-50 dB
$1504.42 \leq f < 1554.42$	Linearly increasing from -50 dB to -5 dB
$1554.42 \leq f < 1558.42$	Linearly increasing from -5 dB
$1558.42 \leq f \leq 1591.92$	0 dB
$1591.92 < f \leq 1605.42$	Linearly decreasing to -25.35 dB
$1605.42 < f \leq 1625.42$	Linearly decreasing from -25.35 dB to -50 dB
$1625.42 < f \leq 2000$	-50 dB

Figure D-3 **Frequency Selectivity**

Appendix E

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Appendix F

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Appendix G

Rotorcraft Point-in-Space (PinS) Approach Operations to Heliports

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G Rotorcraft Point-in-Space (PinS) Approach Operations to Heliports

G.1 General

The material in this appendix applies to rotorcraft approach operations to heliports only. The specific requirements for these operations can be achieved through various integration techniques without requiring changes to the basic sensor.

G.2 Non-Numeric Deviation

PinS approach testing has been conducted that utilized the display course widths identified in Appendix Q of RTCA/DO-229D. The use of these display course widths provided for excellent flyability and less restrictive obstacle clearance requirements while maintaining the same target level of safety. These course widths for rotorcraft PinS approach operations differ from those described in Section 2.3.11.5.1.1 of this document.

G.2.1 Non-Numeric Lateral Cross-Track Deviation

For helicopter PinS approaches designed relative to an FTP, the course width at the FTP is encoded in the course width field of the final approach segment data block. The special coding of "00" in the runway field is not used. The lateral full-scale deflection of ± 133 m (±440') at the FTP located 3,841 m (12,600') from the GARP results in excellent flyability. The lateral angular splay is ±2°.

For simplicity, the nominal location of the point at which the decision altitude (DA) is reached when established on the glide path or the missed approach point (MAP) and the FTP are co-located. In order to provide sufficient distance for deceleration, the FTP should be located no closed than 793 m (2,600') to the heliport. The optimum distance from the FTP to the heliport is 1,204 m (0.65 NM) with a maximum distance of 3,056 m (1.65 NM). The maximum track change at the FTP is 30°. Lateral course width sensitivity and orientation of FTP relative to the heliport are depicted in Figure G-1.

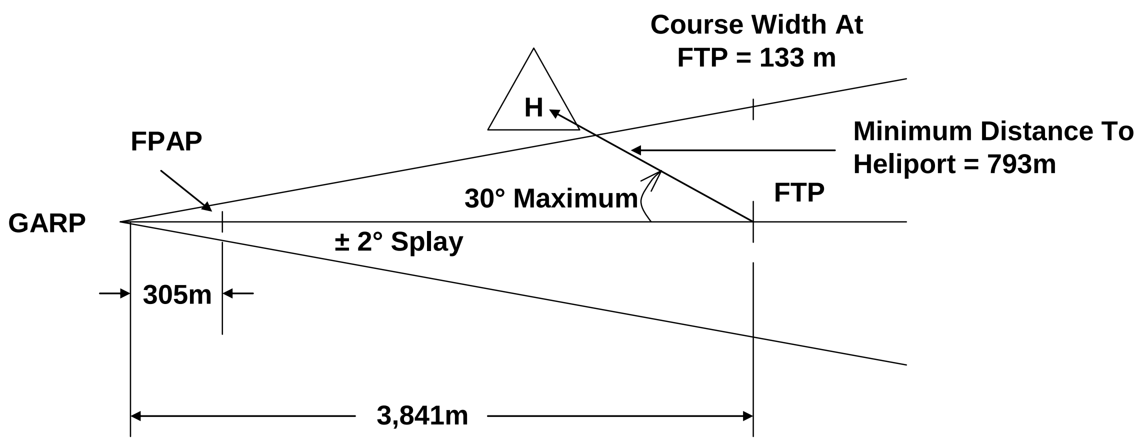

Figure G-1 Lateral Display Scaling and Orientation of the FTP to the Heliport

G.2.2 Non-Numeric Vertical Deviation

For helicopter PinS approaches, the ± full-scale deflection is $\alpha_{vert,FS} = \pm$(FAS glide path angle)/4. Closer than 15 meters / {tan (FAS glide path angle)} to the origin, the deviation becomes linear with full-scale displacement (FSD) of ±15 meters. See Figure G-2.

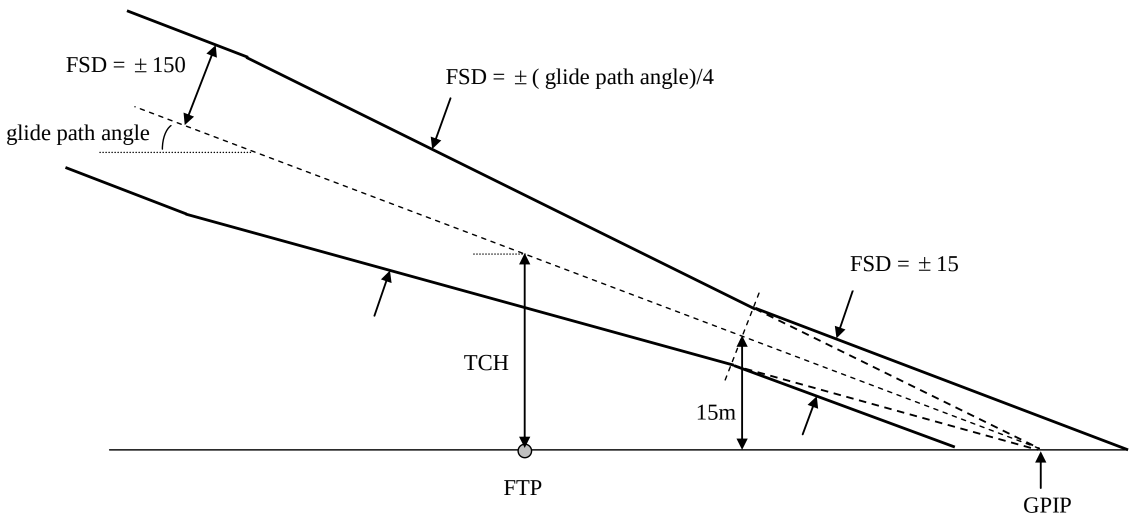

Figure G-2 Vertical Display Scaling

G.2.3 Encoding of a PinS FAS Data Block.

The FAS data block field lengths, range of values and encoding resolutions identified in Table 2-19 of RTCA/DO-246D must be adhered to. Encoding of the helicopter PinS approach procedures conforms to paragraph 2.4.6 and Table 2-19 of RTCA/DO-246D. The following additional information is provided.

a) All procedures are coded relative to an FTP.

b) Operation type: Helicopter PinS procedures are coded as straight-in procedures (=0)

c) Runway Number: The field is encoded with the PinS final approach course rounded to the nearest 10º.

d) Runway Letter: The field is left blank.

e) LTP/FTP Latitude: The FTP latitude is encoded using the same convention as in Table 2-19.

f) LTP/FTP Longitude: The FTP longitude is encoded using the same convention as in Table 2-19.

g) LTP/FTP height: The FTP height is encoded using the same convention as in Table 2-19.

h) Δ FPAP Latitude and Δ FPAP Longitude: They are encoded so the FPAP distance from the FTP equals 3,536 m.

i) Approach Threshold Crossing Height (TCH): The field is coded as the height the PinS nominal glide path angle crosses above the FTP Height.

j) Course Width at Threshold: The course width at the FTP is encoded as 133 m.

k) Δ Length Offset: Since there is no runway the field is coded as "0".

Note: *When the final approach segment data block is encoded relative to an FTP for PinS operations, the course width at the FTP is established with the encoding of the course width field and the runway field is not encoded as "00".*

G.2.4 Flight Director and Autopilot Displacement Gains

Flight test results indicate tighter course displacement gains, both horizontal and vertical, may be used whenever the flight director and/or autopilot is used to fly the navigation deviation signals in order to reduce Flight Technical Error (FTE). Horizontal and vertical deviation scaling displayed to the pilots will, however, remain the same as Sections G.2.1 and G.2.2 above, whenever increased flight director and autopilot gains are employed.

G.3 Primary Navigation Display

There are no additional display requirements for helicopter PinS approaches.

G.4 Alerts and Advisories

This section is reserved.

G.5 Protection Level

G.5.1 Lateral Protection Level

The same lateral protection level (LPL_{Apr}) can be used for approaches to runways and heliports.

G.5.2 Vertical Protection Level

The same vertical protection level (VPL_{Apr}) can be used for approaches to runways and heliports.

G.5.3 Other Protection Level Considerations

Currently, there are no protection levels identified for the velocity outputs from the LAAS equipment. At rotorcraft approach speeds, velocity errors could dominate position error in terms of achieved navigation system performance, in particular, when tracking a commanded deceleration profile. Tightly coupled GPS-IRU velocity estimates or inertially aided velocity estimates through an FMS are more tolerant of GPS velocity error than pure PVT (position, velocity, time) input to a navigator.

G.6 Autopilot Considerations

If coupled autopilot or flight director approaches are to be implemented, then the autopilot or flight director will be capable of tracking the lateral and vertical deviation profiles at speeds below the certified V-mini for the rotorcraft being flown. Stable coupled flight below V-mini is required to insure that the coupled autopilot or flight director approach will remain stable at V-mini and above with acceptable FTE.

G.7 Heliport Approach Databases

Heliport procedure design characteristics differ considerably from runway procedure design characteristics. Databases must contain sufficient information to properly construct the rotorcraft instrument approach procedure.

G.8 References

(1) FAA Order 8260.3B, "Terminal Instrument Procedures".

(2) Draft FAA Order 8260.42B, "Helicopter Global Positioning System (GPS) Non-precision Approach Criteria", US Department of Transportation Federal Aviation Administration, Publication Pending.

(3) FAA Order 8260.54A, "The United States Standard for Area Navigation", US Department of Transportation Federal Aviation Administration, December 2007.

(4) RTCA / DO-246D, GNSS Based Precision Approach Local Area Augmentation System (LAAS) Signal-In-Space Interface Control Document (ICD).

Appendix H

Test Considerations

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H. Test Considerations

H.1 Accuracy Test Statistical Justification

The accuracy test is designed to ensure an acceptably low risk of passing for equipment that does not meet the required accuracy as represented by its σ_{noise} output. This beta risk (β) is formally specified as:

$$\beta = \Pr\{\text{test is passed} \mid \sigma > 1.1\sigma_{noise}\} \geq 0.1$$

where σ represents the actual RMS accuracy of the equipment. This risk specification can be used to develop a pass criterion for the normalized accuracy statistic RMS_PR(M) as defined in Section 2.5.3.2 of this MOPS. Under the steady-state tracking conditions specified in Section 2.3.6.2 in this MOPS, assuming that the residual pseudorange errors are zero mean, normally distributed, random variables with variance σ^2, it can be shown that the probability distribution of RMS_PR(M) is equal to the Chi distribution with NIS degrees of freedom and with parameter σ/σ_{noise}:

$$\Pr\{RMS\_PR(M) \leq X\} = \chi(X, \sigma/\sigma_{noise}, NIS)$$

where:

NIS is the number of independent samples as defined in Section 2.5.3.2 of this MOPS.

The pass threshold T can be found as a function of NIS by solving the implicit equation:

$$\chi(T, 1.1, NIS) = 0.1$$

The solution is graphed as a function of NIS in Figure H-1.

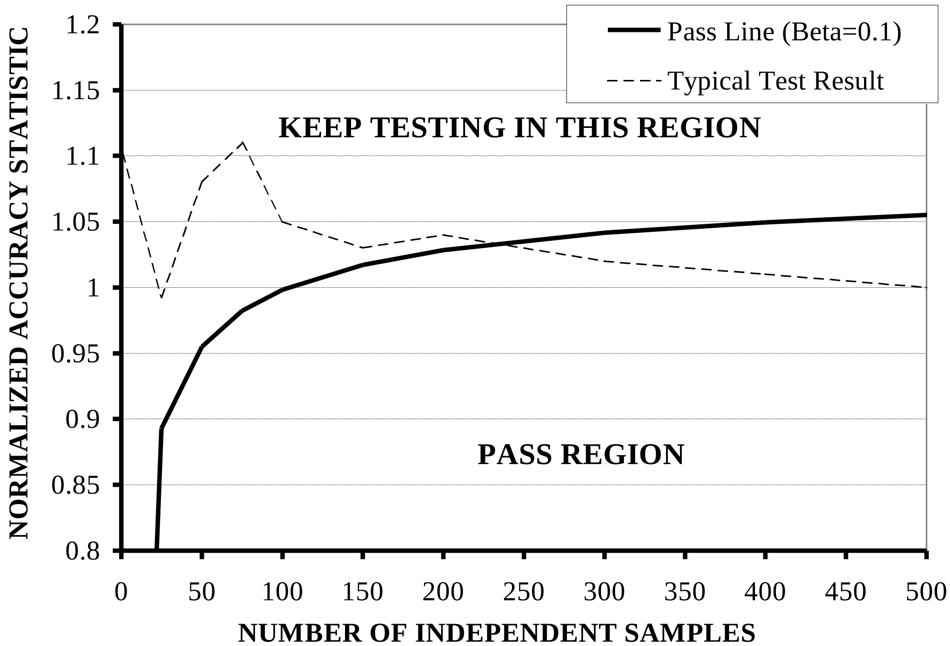

Figure H-1. Pseudorange Accuracy Test Pass Criteria

The probability of passing the test for equipment that meets the requirement, PP(NIS), can be determined by evaluating the following Chi distribution:

$$PP(NIS) = \chi(T, 1, NIS)$$

The pass probability as a function of NIS is shown in Figure H-2.

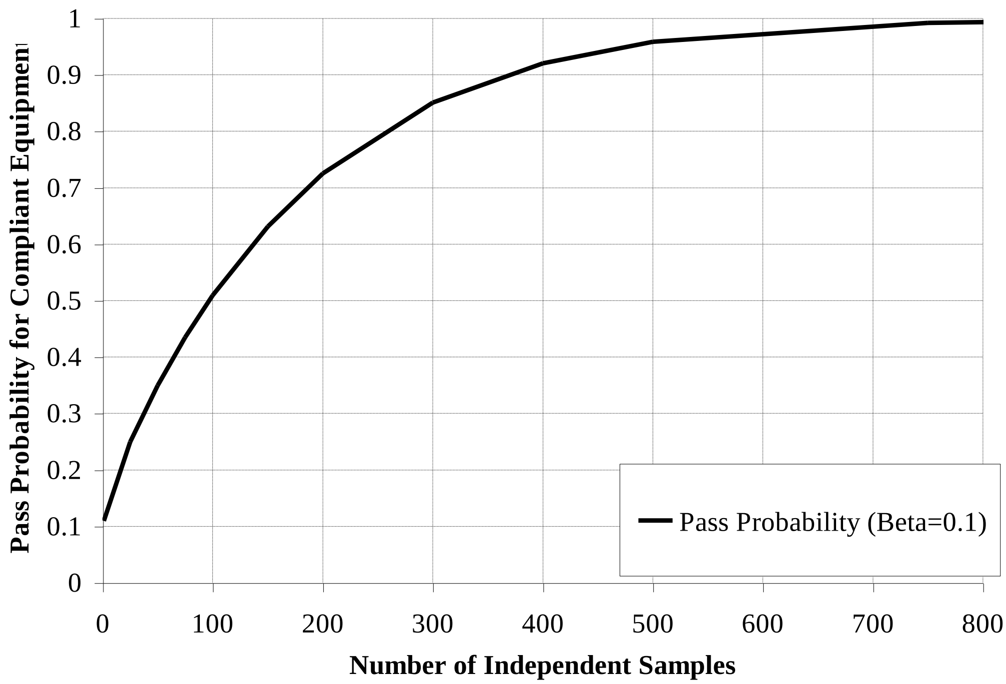

Figure H-2. Pseudorange Accuracy Test Pass Probability

H.2 Message Failure Rate Test Statistical Justification

Testing of VDB Message Failure Rate (MFR) is based on a series of test conditions. 10,000 messages are collected for each test condition, and up to 15 failures are allowed. A receiver with an actual MFR of 0.001 has a 95% chance of passing a given test condition, based on the binomial distribution. A receiver with an actual MFR of 0.002 has a 15% chance of passing a given test condition.

H.3 Example Test Set-up and Compensation of Signals, Noise and Interference

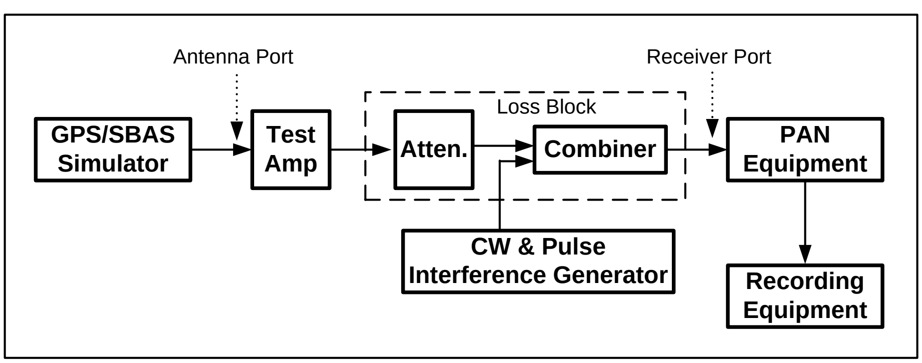

FIGURE H-3 EXAMPLE TEST SET-UP

H.3.1 Description of the Test Set-up

The test set-up in Figure H-3 approximates a real installation, where satellites and the radiation pattern of the antenna are replaced by the GPS/SBAS simulator, the active portion of the antenna is replaced by a test amplifier with the same gain as the active antenna preamplifier, and the loss block has the same total loss as an installation. The loss block is composed of a variable attenuator, a combiner, and associated cabling from the test amplifier output to the receiver port for a total loss of L_{Block}. The loss from the combiner input to the receiver port is $L_{combiner}$.

This set-up uses a test amplifier with an adjustable noise figure in order to insert the appropriate broadband noise at the input of the amplifier. An alternate set-up would include a noise generator and a combiner prior to the test amplifier, and both the simulator output and noise generator would have to be adjusted to achieve the desired signal and broadband noise (specified as noise density in the test procedures) at the input to the test amplifier. The amplifier also has adjustable gain, G_{Amp}. An alternate test set-up could use the active subassembly of the antenna, provided the subassembly was calibrated to have known gain and noise figure and all signal and interference levels adjusted to compensate for any difference with the specified characteristics of the integrated antenna including production variations.

The CW and pulse interference is inserted after the test amplifier. It is calibrated to output a signal with power $C_{interference}$ as referenced to the input of the combiner. It could also be inserted prior to the test amplifier, and the simulated power level would have to account for any filtering in the amplifier (assuming the inserted power were within the operating range of the amplifier).

In this example, the equipment under test is designed for use with a minimum standard antenna. The installation criteria is as follows:

a) L_{max} = 15 dB and L_{min} = 5 dB.
b) $N_{sky,antenna}$ = -172.5 dBm/Hz.
c) Gain of the active portion of the antenna $G_{Ant} = 30 \pm 3$ dB.
d) Active antenna Selectivity per DO-301, for example -50 dB at 1626 MHz.

The equipment is calibrated to determine noise levels and loss. In this example, the following values are used:

a) GPS/SBAS Simulator: $I_{Simulator}$ = -174 dBm/Hz with an adjustable signal level of $C_{Simulator}$ both referred to the input of the test amplifier.
b) Combiner with loss $L_{Combiner}$ = 5 dB from its input to the Receiver Port.

H.3.2 Use of the Test Set-up for the Accuracy Test (See 2.5.3.2.1)

As the broadband noise is generated by the simulator and the adjustable noise figure of the amplifier, the appropriate noise figure must be determined for the accuracy tests. Two levels must be computed for the minimum signal level tests since some tests include external broadband interference and some do not. An additional level must be determined for the test with all satellites at maximum power.

For the minimum signal level tests, the test amplifier gain (G_{Amp}) is set to 27 dB (minimum G_{Ant}) and the total loss to 15 dB ($L_{Block} = L_{max}$). A ten-channel simulator is used, with one GPS satellite at maximum power (-121 dBm), seven minimum-power GPS satellites (-134 dBm) and two minimum-power SBAS satellites (-134 dBm).

Note: Noise due to SBAS satellites must be accounted for whether the GBAS receiver tracks these satellites or not. GBAS equipment not tracking SBAS satellites could account for SBAS satellite noise analytically without actually stimulating the GBAS equipment with SBAS satellite signals in addition to GPS signals.

(Editorial note: Make sure test requirements specifically say you have to include GPS and SBAS satellites in the noise computation.)

In order to determine the required GNSS test noise, the effective noise of the satellites simulated in the test is subtracted from the total GNSS noise of -171.9 dBm/Hz.

Using the equation in 2.5.3.2.1:

$$\begin{aligned} I_{Test} &= 10\log10[(N_{GL})10^{I_{GL}/10} + (N_{GH})10^{I_{GH}/10} + (N_{SL})10^{I_{SL}/10} + (N_{SH})10^{I_{SH}/10}] \\ &= 10\log10[(7)10^{-196.5/10} + (1)10^{-183.5/10} + (2)10^{-198.3/10} + (0)10^{-179.8/10}] \\ &= -182.0 \text{ dBm/Hz} \end{aligned}$$

and

$$\begin{aligned} I_{GNSS,Test} &= 10\log10[10^{I_{GNSS}/10} - 10^{I_{Test}/10}] \\ &= 10\log10[10^{-171.9/10} - 10^{-182.0/10}] \\ &= -172.4 \text{ dBm/Hz} \end{aligned}$$

The noise that must be generated by the test amplifier is determined by subtracting the simulator noise from the total broadband noise for the test (the sum of $N_{sky,antenna}$, $I_{GNSS,Test}$ and $I_{Ext,Test}$). The external noise is -170.5 dBm/Hz for those cases that include external noise, so that the equivalent test noise that must be generated is:

$$\begin{aligned} I_{Total,Test} &= 10\log10[10^{N_{sky,antenna}/10} + 10^{I_{GNSS,Test}/10} + 10^{I_{Ext,Test}/10} - 10^{I_{Simulator}/10}] \\ &= 10\log10[10^{-172.5/10} + 10^{-172.4/10} + 10^{-170.5/10} - 10^{-174/10}] \\ &= -167.9 \text{ dBm/Hz} \end{aligned}$$

The equivalent noise factor is determined as:

$$NF_{Amp(ext)} = 10\text{Log}10(1 + 10^{I_{Total,Test}/10}/k/290) = 7.06 \text{ dB}$$

For those tests without external broadband noise (e.g., CW and pulse interference cases and to expedite initial acquisition in other tests):

$$
\begin{aligned}
I_{Total,Test} &= 10\log10[10^{N_{sky,antenna}/10} + 10^{I_{GNSS,Test}/10} - 10^{I_{Simulator}/10}] \\
&= 10\log10[10^{-172.5/10} + 10^{-172.4/10} - 10^{-174/10}] \\
&= -171.3 \text{ dBm/Hz}
\end{aligned}
$$

And the equivalent noise factor is determined as:

$$NF_{Amp(no\ ext)} = 10\text{Log}10(1 + 10^{I_{Total,Test/10}}/k/290) = 4.55 \text{ dB}$$

The CW and pulse interference levels must be adjusted based on the specified antenna gain, antenna frequency selectivity and installation loss. To determine the power level at the signal generator the loss of the combiner must be offset. For example, for the +8 dBm CW signal at 1626 MHz:

$$
\begin{aligned}
C_{Interference,CW} &= I_{Int} + G_{Amp} - \text{Selectivity} - L_{Block} + L_{Combiner} \\
&= +8 + 27 - 50 - 15 + 5 \\
&= -25 \text{ dBm}
\end{aligned}
$$

The pulse power is limited by the maximum output of the active antenna (P_{out}):

$$
\begin{aligned}
C_{Interference,pulse} &= P_{out} - L_{Block} + L_{Combiner} \\
&= +20 - 15 + 5 \\
&= +10 \text{ dBm}
\end{aligned}
$$

Repeating the analysis for the maximum signal case yields the following:

$L_{Block} = L_{min} = 5$ dB.
G_{Amp} = maximum $G_{Ant} = 33$ dB.
Eight maximum level GPS satellites: $C_{Simulator} = -121$ dBm.
Two maximum SBAS satellites: $C_{Simulator} = -115.5$ dBm

$$
\begin{aligned}
I_{Test} &= 10\log10[(N_{GL})10^{I_{GL}/10} + (N_{GH})10^{I_{GH}/10} + (N_{SL})10^{I_{SL}/10} + (N_{SH})10^{I_{SH}/10}] \\
&= 10\log10[(0)10^{-196.5/10} + (8)10^{-183.5/10} + (0)10^{-198.3/10} + (2)10^{-179.8/10}] \\
&= -172.5 \text{ dBm/Hz}
\end{aligned}
$$

$$
\begin{aligned}
I_{GNSS,Test} &= 10\log10[10^{I_{GNSS}/10} - 10^{I_{Test}/10}] \\
&= 10\log10[10^{-171.9/10} - 10^{-172.5/10}] \\
&= -181.4 \text{ dBm/Hz}
\end{aligned}
$$

For Broadband External Interference Noise of $I_{Ext,Test} = -170.5$ dBm/Hz:

$$
\begin{aligned}
I_{Total,Test} &= 10\log10[10^{N_{sky,antenna}/10} + 10^{I_{GNSS,Test}/10} + 10^{I_{Ext,Test}/10} - 10^{I_{Simulator}/10}] \\
&= 10\log10[10^{-172.5/10} + 10^{-181.4/10} + 10^{-170.5/10} - 10^{-174/10}] \\
&= -169.5 \text{ dBm/Hz}
\end{aligned}
$$

So:

$$NF_{Amp,ext} = 10\text{Log}10(1 + 10^{I_{Total,Test}/10}/k/290) = 5.82 \text{ dB}$$

Appendix I

Service Types, Facility Classifications and Airborne Equipment Classification

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I Background

This Appendix presents an overview of a classification scheme for GBAS Services and equipment. The concepts of Service Types, Ground Facility Classifications and Airborne Equipment Classifications are defined.

To facilitate interoperability and consistent, predictable performance, the airborne and ground subsystem performance requirements for GBAS are organized into matched sets that are intended to be used in conjunction. These matched sets of performance and functional requirements are referred to collectively as GBAS Service Types (GST). The specific requirements for the Ground and Airborne subsystems are then organized by Ground Facility Classifications (GFC) and Airborne Equipment Classifications (AEC) which in turn reference the GBAS Service Types.

Figure I-1 illustrates how the concepts of facility classification and service type are related.

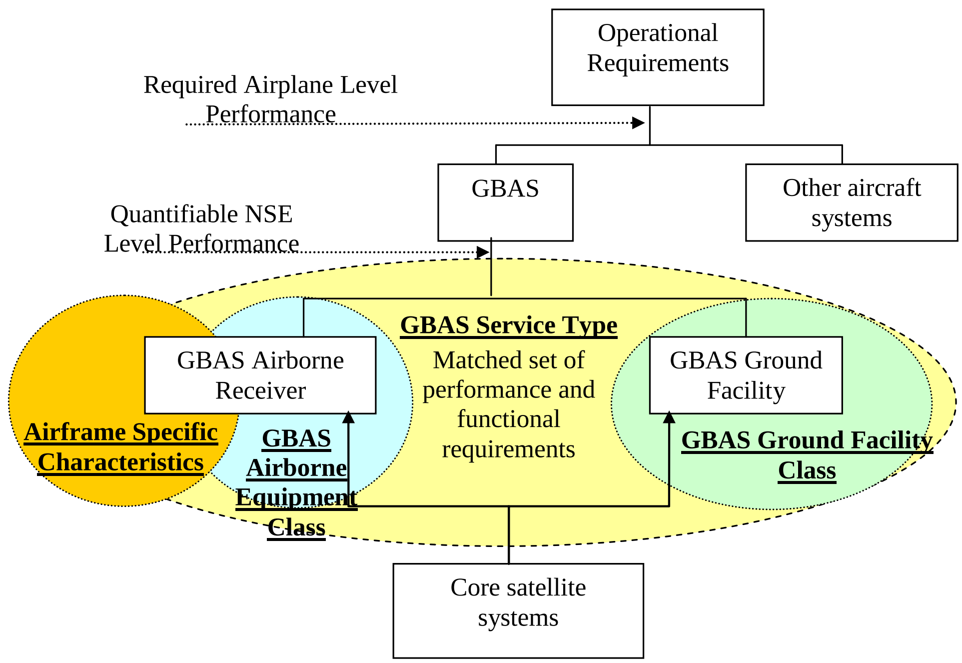

Figure I-1 Service Types, Facility Classifications and Airborne Equipment Classes

I.1 GBAS Service Types

A GBAS supports two basic types of service, Approach Services and the GBAS Positioning Service.

- The GBAS Positioning Service GBAS/PS allows the user to compute an accurate differential position solution with integrity. Only one type of positioning service is defined.
- A GBAS Approach Service enables the user to compute an accurate differentially corrected position solution, but also includes the definition

of a reference path so that the airborne equipment can compute guidance information (deviations) relative to the reference path. Several different types of GBAS Approach Service are defined which provide different levels of performance.

I.2 GBAS Approach Service Types (GAST)

A GBAS Approach Service Type is defined as the matched set of airborne and ground performance and functional requirements that are intended to be used in concert in order to provide approach guidance with quantifiable performance.

I.2.1 GAST A, B and C

Four GBAS Approach Service Types are defined. Service Types A-C are the services that are currently described in the SARPs [ICAO Annex 10 Volume I through amendment 82 and identified with the terms APV I, APV II, and CAT I, respectively. Although the SARPs do not characterize the collection of airborne and ground functional and performance requirements as service types, the definition can be applied. It should be recognized that the resultant levels of position domain navigation performance defined in table A-3.7.2.4-1 of the ICAO Annex 10 SARPs are the result of a specific combination of ground and airborne functional and performance requirements. In other words, the standard signal-in-space performance levels defined in table A-3.7.2.4-1are a characteristic of the Service Type. However, the position domain based signal-in-space performance requirements are not a complete definition of the service.

This MOPS applies to GBAS airborne equipment. GBAS Service Types A & B are included in the classification scheme to accommodate GRAS systems that may provide for only APV I or APV II operations. This MOPS will not include requirements for GAST A or B.

I.2.2 GAST D

The fourth service type, GAST D is defined by this MOPS, the LAAS ICD DO-246D, and ICAO NSP CSG proposed SARPs revisions for GBAS GAST D. Just as with the other service types, GAST D defines a matched set of standard airborne and ground functional requirements that when combined results in position and guidance information with quantifiable performance. However, GAST D is different than the other defined services in that some aspects of the airborne functional requirements are not standardized. These non-standard characteristics allow the position domain NSE performance of the system to be tailored to the needs of a specific aircraft implementation.

Unless otherwise noted, performance requirements for GAST C are met by GAST D. GAST D includes some additional requirements not included in GAST C that are intended to support CAT II/III operations. The ground subsystem functional and performance requirements for GAST D are a superset of the requirements for GAST C, (i.e., all GAST D capable ground subsystems will support GAST C). From the airborne equipment perspective, the functional requirements depend on the active service type. Although the airborne functional requirements are somewhat different between GAST C and GAST D, the Signal in Space performance achieved is the same with one small exception. For GAST D, the mitigation of errors induced by anomalous ionospheric conditions has been allocated to the airborne system. Consequently, the SIS integrity bounding process (i.e., VPL and HPL) does not necessarily bound the errors due to the anomalous ionospheric conditions. For all other error contributors, the SIS bounding provided by the protection level computations is equivalent between GAST C and GAST D.

For GAST D, the additional accuracy performance requirements (beyond the baseline SIS requirements defined for GAST C) are specified in the pseudorange domain. When combined by the airborne equipment, the resultant position domain accuracy depends on the specific geometry screening done by the airborne equipment. There is a functional requirement included in GAST D for the airborne equipment to perform geometry screening to limit the normal and faulted NSE performance at the output of the system. However, the specific metrics to be used by the airborne in the screening will depend on the NSE performance required by the specific airplane type in order to meet the relevant touchdown performance requirements. Hence no unique standard, position domain NSE level accuracy is specified for this Service Type. The same holds true for Integrity and Continuity. For GAST D, monitoring performance requirements will be specified in the pseudorange domain. The acceptable airplane level performance is determined by the end-user and the service provider is only responsible for ensuring that the signals provided by the ground station meets the pseudorange domain monitoring requirements and performs all other functional requirements necessary so that the user can determine the appropriate NSE characteristics in the position domain under faulted and fault free conditions. Similarly, Continuity is defined in terms of the continuity of the service actually provided by the ground station and not at the output of a ‘fault free’ receiver. The determination of position domain NSE continuity and the assessment of the suitability of that continuity for the operational intent is the responsibility of the end user.

I.3 GBAS Facility Classifications

A GBAS Facility Classification (GFC) is composed of the following elements:

Facility Approach Service Type (FAST) – This is a collection of letters from A to D indicating the Service Types that are supported by the ground facility. For example, FAST C denotes a ground station that meets all the performance and functional requirements necessary to support Service Type C. As another example, a FAST D ground station supports approaches with service types C and D. (Recall that GAST D is a superset of GAST C, so a FAST D ground station will by definition support GAST C service.)

Ranging Source Types: Indicates what ranging sources are augmented by the ground facility. The codings for this parameter might be as follows:

G1 - GPS
G2 - SBAS
G3 - GLONASS
G4 - Galileo
G5+ - TBD

Note: The specific codification for the ranging types has not been determined yet. This MOPS applies only to GBAS that augments GPS L1. Hence this classification parameter is not yet relevant for this MOPS.

Facility Coverage: Defines coverage of the positioning service. *(Note that coverage for specific approaches is covered below as part of the Approach Facility Designations)*. The facility coverage is coded as 0 for Ground facilities that do not support the Positioning Service. For other cases, the facility coverage indicates the radius of Dmax expressed in nautical miles.

Polarization: Defines the polarization of the VHF Data Broadcast (VDB) signal. E indicates elliptical polarization and H indicates horizontal polarization.

I.3.1 Facility Approach Service Type (FAST)

The facility classification scheme for GBAS includes an indication of which Service Types the ground station can support. What this means is, the ground station meets all the performance requirements and functional requirements such that a compatible airborne user can apply the information from the ground station and have quantifiable performance at the output of the processing. It does not necessarily mean that the ground facility supports all service types on every runway end. Which Service Types are supported on a given runway end is indicated as part of the Approach Facility Designation.

I.3.2 GBAS Facility Classification Examples

The facility classification for a specific facility would be specified by a concatenated series of codes for the elements described in section I.3. For example a facility with the designation of: GFC – C/G1/50/H, would denote a ground facility that supports Service Type C on at least one approach, using GPS L1 ranges only, with a positioning service available to a radius of 50 nm from the GBAS reference position and a VDB that broadcasts in Horizontal polarization only. Similarly: GFC - D/G1G2G4/0/E would denote a ground facility that supports at least one approach with a service type of C and D, provides corrections for GPS, Galileo and SBAS satellites, does not support the positioning service and broadcasts on Elliptical polarization. In general:

GFC = Facility Approach Service Type/Ranging Source Type /Facility Coverage/Polarization

I.4 Approach Facility Designations

A GBAS ground station may support many approaches to different runway ends at the same airport or even runways at adjacent airports. It is even possible that a GBAS will support multiple approaches to the same runway end with different Types of Service (intended to support different operational minimums). Each approach provided by the ground system may have unique characteristics and in some sense may appear to the user to be a separate facility. Therefore, in addition to the GBAS Facility Classification, a system for classifying or designating the unique characteristics of each individual approach path is needed. For this purpose a system of Approach Facility Designations is defined. Figure I-

2 illustrates the relationship between GBAS Facility Classifications and Approach Facility Designations.

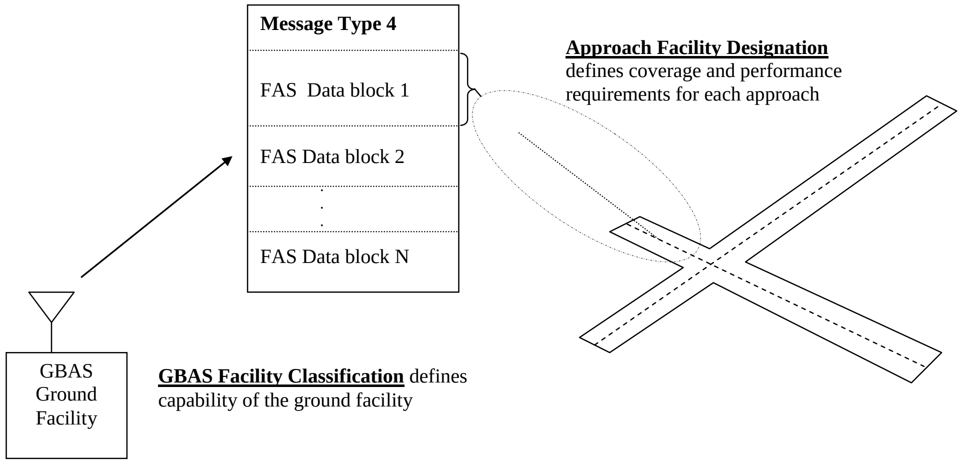

Figure I-2 Relationship between GBAS Facility Classification and Approach Facility Designation

A proposal for GBAS Facility Classification, Approach Facility Classification and GBAS Airborne Equipment Classification is given in the following sections.

I.4.1 Approach Facility Designation Elements

Each approach supported by a GBAS can be characterized by an Approach Facility Designation (AFD). The AFD is composed of the following pieces of information:

GBAS Identification – Indicates the GBAS facility identifier that supports the approach (4-character GBAS ID).
Approach Identifier – This is the approach identifier associated with the approach in the Message Type 4 data block. It is 4 characters and must be unique for each approach within radio range of the GBAS facility.
Channel Number – This is the channel number associated with the approach selection. It is a 5 digit channel number in the range 20001 to 39999.
Approach Coverage – Associated with each published approach, coverage. This is a number indicating the height above the runway for which the GBAS signal has been verified to meet the minimum signal strength. A value of 0 indicates the VDB signal should be available to 7 ft above the ground and along the runway, and therefore the ground facility should support autoland on that runway.
Supported Service Types – Designates the GBAS Service Types (A-D) that are supported for the approach by the ground subsystem. This field can never be given a value greater than the Facility Approach Service Type for the GBAS ground station that supports the approach.

I.4.2 Approach Facility Designation Examples

The Approach Facility Designation consists of the concatenation of the parameters defined in section I.4.1 as: GBAS ID/Approach ID/ranging sources/Approach Coverage/ Required Service Type. An example application of this concept to a particular approach at the US Washington, DC Ronald Reagan International Airport would be:

"LDCA/GDCA/21279/100/CD"

where:

- LDCA indicates the approach is supported by the LAAS installation at DCA
- GDCA indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "GDCA".
- 21279 is the 5-digit channel number used to select the approach
- 100 indicates the GBAS coverage extends to 100 ft above the touchdown point (which is consistent with minimum coverage for a CAT I approach with a DH of 200 ft.
- CD indicates that Service Types C and D are supported by the ground station for the approach

Another example application of this concept to a particular approach at Boeing Field would be:

"LBFI/GBFI/35789/0/C"

where:

- LBFI indicates the approach is supported by the GBAS installation at BFI (with GBAS Station identifier LBFI).
- GBFI indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "GBFI".
- 35789 is the 5-digit channel number used to select the approach
- 0 indicates the GBAS coverage extends to at least 7 ft above the runway and has sufficient coverage to support rollout operations.
- C indicates the required Service Type for the approach is GAST C.

I.5 GBAS Airborne Equipment Classification

GBAS airborne equipment may or may not support multiple types of approach service that could be offered by a specific Ground Facility. The GBAS Airborne Equipment Classifications (GAEC) specifies which subsets of potentially available services types the airborne equipment can support. The GAEC includes the following elements:

Airborne Approach Service Type (AAST) – This is a series of letters in the range from A to D indicating which Service Types are supported by the airborne equipment. For example, AAST C denotes airborne equipment that supports only GAST C. Similarly AAST ABCD indicates the airborne equipment can support GASTs A, B, C & D. For airborne equipment, stating only the highest Service Type is insufficient as not all airborne equipment is required to support all Service Types. For example, a particular type of airborne equipment may be classified as AAST D, meaning the airborne equipment support GASTs C and D (but not A or B).

Ranging Source Types**: -** This field indicates what ranging sources can be used by the airborne equipment. The proposed coding is the same as for the Ground Facility Classification (see section I.3 above).

Other elements may be required for the airborne equipment classification

I.5.1 GBAS Airborne Equipment Classification Examples

GBAS Airborne Equipment Classifications consist of a concatenated series of codes for the parameters defined in Section I.5. For example:

GAEC – C/ G1

denotes airborne equipment that support only GAST C and uses only GPS ranges. Similarly:

GAEC – ABC/G1G4

denotes airborne equipment that supports all GASTs except Service Type D and uses both GPS and Galileo.
Finally:

GAEC – D/G1G2G4

Denotes airborne equipment that supports GASTs C and D and uses GPS, Galileo and SBAS ranging sources.

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Appendix J

Relationship Between Airborne Receiver Geometry Screening and Airworthiness Analyses

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J Relationship Between Airborne Receiver Geometry Screening and Airworthiness Analyses

J.1 Introduction

The purpose of this appendix is to describe an example means for deriving the GAST D aircraft tailored geometry screening parameters to support demonstration of conformance with existing and future potential airworthiness requirements that may be applied to GBAS. Airborne satellite geometry screening parameters may be derived as a function of airplane performance in terms of total system error and GBAS ground and airborne error monitoring requirements.

This introduction provides a brief overview of three key airworthiness requirements used in the derivation of the ground monitor requirements, the resulting ranging source fault monitoring requirements for the ground subsystem and the airborne satellite geometry screening requirements. Section J.2 assumes that each requirement used in the ground monitor performance derivation corresponds to an airworthiness requirement to be applied for GBAS. Section J.2 provides an example method for deriving the required geometry screening parameters that is based on the ground subsystem's ranging source fault monitor performance and airplane performance in terms of probability of exceeding each such airworthiness requirement.

J.1.1 Airworthiness Requirements

Three airworthiness requirements have been selected and adapted for use in the derivation of the Annex 10 ground subsystem's ranging source fault monitoring requirements. These requirements are located in the following documents:

1. AC 120-28D, Appendix 3, Section 6.3.1 (Nominal Performance)
2. AC 120-28D, Appendix 3, Section 6.4.1 (Performance with Malfunction)
3. JAR AWO Subpart 1 (Performance Demonstration Limit Case Conditions)

Item (1) is applicable to GBAS as written. Items (2) and (3) have been adapted by the GBAS community and could result in new airworthiness requirements for GBAS. The requirements have been given monikers (Nominal Condition, Malfunction Condition, and Limit Condition respectively) that relate to their *original* purpose within the airworthiness documents; these names are *not* intended to be indicative of the role they play in the proposed ICAO Annex 10 material. For example, the malfunction condition does not address ground or airborne subsystem malfunctions and the limit condition does not address performance at a single extreme value.

The resulting three conditional requirements include a group of performance parameters, each with an associated maximum probability that the parameter may exceed a specified limit for that condition. The performance parameters include longitudinal and lateral gear touchdown locations, structural load, and airplane attitude at touchdown.

These requirements and their treatment based on GBAS requirements and airplane performance are described in more detail in the following sections.

J.1.2 GBAS Errors and Monitoring Requirements

GBAS measurement errors and their probability distributions directly impact the airplane performance relative to the airworthiness requirements in the previous section.

The ground subsystem requirements in the proposed Annex 10 material define a limit on the probability that the range error contribution only due to a ranging source fault will go undetected by ground monitoring (P_{md}) for more than 1.5 seconds. Figure J-1 shows a graphical depiction of the P_{md} limit, or constraint region, as a function of the faulted ranging source error magnitude ($|E_R|$) from the proposal below for convenience. Note that this requirement is still under development and subject to validation; however, the general discussion of this appendix is expected to remain applicable.

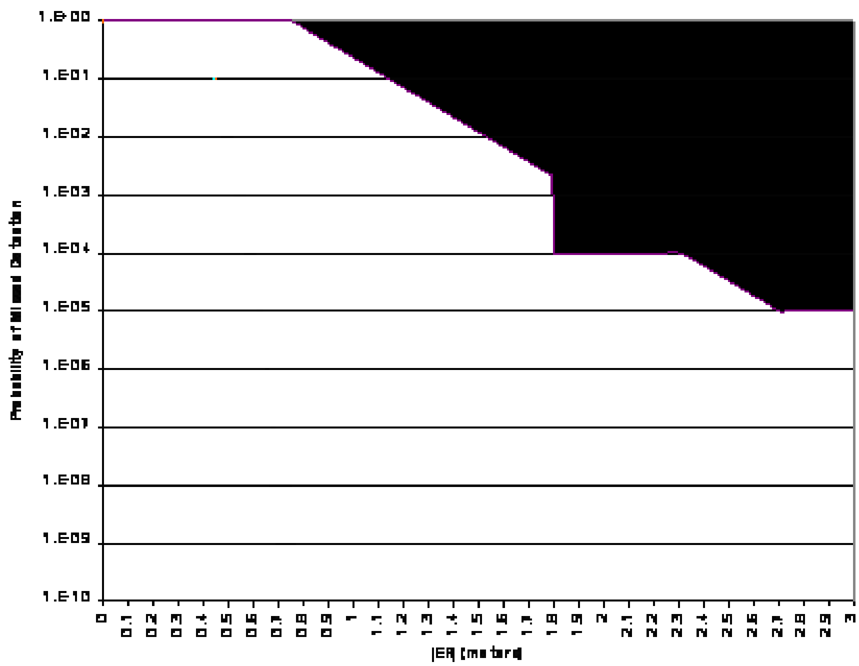

Figure J-1 - Limit on the Probability that a Range Error Due to a Fault with Magnitude $|E_R|$ Goes Undetected by Ground Reference Station Monitoring

The constraint region was derived based on the three airworthiness requirements referenced in the previous section as well as assumptions of aircraft performance and the relationship between the navigation system errors and aircraft performance. (The purpose of new airworthiness requirements would be to establish the compatibility of the actual aircraft performance with the constraint region standardized within Annex 10.) The malfunction driven requirement limits the product of the prior probability of a fault and the probability of missed detection of errors due to the fault to a probability smaller than 10^{-9} for range errors due to a fault that are larger than 1.8 meters. The limit condition drives the shape of the ground monitor requirements at smaller values and continues to a probability of 10^{-5}, such that the probability of an unsuccessful landing for errors larger than 2.7 meters is limited to 10^{-5}.

This P_{md} limit for ground monitors can serve as a bound on the size and probability of ranging source errors due to faults that are monitored by the ground equipment. Note that some errors are monitored as part of the airplane design. The actual monitor performance or error response of the airplane design may be characterized and used in the airworthiness proof and does not necessarily have to be shown to meet this ground monitor P_{md} limit.

J.1.3 Airborne Geometry Screening Techniques

Airborne screening required in Section 2.3.9.4 consists of two main techniques: protection level limits and limits on maximum projection factors from the range domain to the position domain. Protection level limits, or alert limits, are defined as maximum values for GAST D, and there are no limits on the projection factors that are required as a maximum. Given the performance of any range error monitors and airplane total system error performance, the ability to specify further limits on protection levels and projection factors is a tool that can enable proof of airworthiness. This section briefly overviews how this may be accomplished, and section J.2 provides more detailed examples.

Selection of a smaller alert limit reduces the fault-free navigation sensor error (NSE) standard deviation that must be assumed for the worst case satellite geometry. Because of the nature of the protection level computations, the standard deviation of the NSE can be related to the alert limit. For example, in the case of the vertical, the standard deviation of NSE for the worst fault-free satellite geometry may be expressed as follows.

$$\sigma_{ffNSE\_Vert} \leq \frac{VAL}{K_{ffmd}} \tag{1}$$

Since the fault-free NSE is included in the total system error (TSE), along with flight technical error (FTE), the probability of an unsuccessful landing can be reduced through screening of the fault-free NSE via smaller alert limits.

$$\sigma_{TSE} = \sqrt{\sigma_{FTE}^2 + \sigma_{NSE}^2} \tag{2}$$

Selecting smaller limits on maximum projection factors directly limits the projection from the range domain to the position and touchdown domains. For example, in the case of the vertical, if a limit is placed on the maximum magnitude of the vertical projection from the pseudorange domain to the position domain, $S_{Apr\_vert,i}$, then the following relationship is true for a single-satellite fault that dominates the position error.

$$\max(E_V) = E_R * \max(\left|S_{Apr\_vert,i}\right|) \tag{3}$$

Similarly, if a two-satellite fault must be considered, then the second largest magnitude of the vertical projections into the position domain may also be limited. In the geometry screening requirements Section 2.3.9.4 this is specified as a limit of the sum of the maximum two magnitudes, or maxSvert2. The maximum vertical projection magnitude due to the two-satellite fault may be expressed as follows:

$$\max(E_V) = E_{R1} * \max Svert + E_{R2} * (\max Svert2 - \max Svert) \tag{4}$$

Where:

ER1 - is the larger of the two simultaneous range errors

ER2 - is the second range error

maxSvert - is max($|S_{Apr\_vert,i}|$)

maxSvert2 - is max($|S_{Apr\_vert,i}| + |S_{Apr\_vert,i}|$)

Note that if ER1 and ER2 may be the same, this expression simplifies to

$$\max(E_V)=E_R * maxSvert2 \tag{5}$$

The geometry screening examples in this appendix are based on the single-satellite fault case. They can also be readily extended for the two-satellite fault case.

J.2 Geometry Screening, Airworthiness, and Airplane Performance

In this section the general equations for touchdown performance are examined and their applicability to the three assumed airworthiness requirements is shown. First, the general expression for probability of an unsuccessful landing is described, then applicability to the three airworthiness criteria is discussed. In each case, example uses of geometry screening limits to meet the assumed longitudinal touchdown airworthiness requirements are discussed. Note that this same technique may be used to show airworthiness for the lateral touchdown and other performance parameters.

J.2.1 Unsuccessful Landing

Longitudinal touchdown distribution is a driving requirement in terms of airplane performance and airworthiness; however, it is not the only requirement. Methods similar to those discussed in this appendix may be applied to additional performance parameters in order to determine compliance with the other dimensions of the airworthiness requirements, such as lateral touchdown, bank angle, etc., in as much as they are dependent on the NSE (both fault-free and faulted). For the remainder of this appendix, the longitudinal touchdown case will be described for example.

Let the following variable describe a probability density function for the location of the touchdown point on the longitudinal axis, x, of the runway for the nominal, fault-free condition:

$$p_{TSE\_LON}(x) \tag{6}$$

This distribution is typically determined as part of the airplane certification process by performing a high-fidelity landing simulation for a particular airplane and autopilot design using a standard GBAS signal model to represent the fault-free NSE for the receiver being used, and using standard models for environmental effects, such as wind. For each airworthiness requirement this distribution may be defined differently.

Then, the generalized probability that a landing is unsuccessful, P_{UL}, is the integral of the touchdown distribution about the region defined as unsuccessful for the particular airworthiness condition.

$$P_{UL} = \int_{UNSUCCESSFUL} p_{TSE\_LON}(x)dx \tag{7}$$

As explained in the next three sections, the unsuccessful region and the touchdown distribution are treated differently for each airworthiness requirement. Next, the regions of success and treatments of TSE for each of the three airworthiness criteria are discussed. Finally, the required geometry screening as a function of airplane performance is described as an example for each of the three criteria.

J.2.2 Nominal Condition

The nominal condition for the longitudinal touchdown case requires that

$$P_{UL} < 10^{-6} \tag{8}$$

for a land short limit of 200 feet and, separately, for a land long limit of 2700 feet. The touchdown distribution used to form P_{UL} for the nominal condition is required to include the effect of all influencing parameters varied according to their expected distributions. The unsuccessful region would be from negative infinity to 200 feet for the land short requirement, and the unsuccessful region for the land long requirement is from 2700 feet to infinity.

Similarly, the variable of interest for each parameter specified in the nominal condition requirements, such as lateral touchdown point, or bank angle at touchdown, must be expressed as a probability density and integrated over the unsuccessful values for the parameter. The result of the integration must be smaller than the requirement for each parameter.

This condition is no change from its treatment for other landing systems, such as ILS. The only difference is that the NSE is described by GBAS NSE that is limited by geometry screening.

An example procedure for deriving the necessary geometry screening to meet airworthiness requirements for the nominal condition, should it be necessary, is to simply reduce the geometry screening parameters until the nominal condition is met and at the same time system availability is maximized. This may become a trade off between alert limit and projection factor reduction.

J.2.3 Limit Condition

Assume that the limit condition for the longitudinal touchdown case requires that the following be demonstrated: Given that a particular fault generates an error, E, at the most critical value for that fault, the probability that the airplane lands shorter than 200 feet from the threshold must be smaller than 10^{-5}, and the probability that the airplane lands longer than 3000 feet from the threshold must also be 10^{-5} with all other effects varying in their expected manner.

The probability of an unsuccessful landing given an error is the joint probability that the fault is not detected that causes an error, *E*, and that the landing will be unsuccessful given an error, *E*:

$$P_{UL}(E) = P_{UL|E}(E)*P_{md}(E) < 10^{-5} \tag{9}$$

The most critical value of *E* for a particular fault may be defined as the *E* at which $P_{UL}(E)$ is maximized.

To form the conditional unsuccessful landing probability, $P_{UL|E}(E)$, a conditional touchdown distribution must be used that would result from a constant bias error in addition to the fault-free NSE and FTE distributions. This must be done for a range of error sizes to form the total conditional probability of an unsuccessful landing as a function of the error. The conditional unsuccessful landing probability is expressed as follows for the land short and land long cases:

$$\text{Land Short } P_{UL|E}(E) = \int_{-\infty}^{200} \mathrm{p}_{\mathrm{TSE\_LON|E}}(\mathrm{x},\mathrm{E})\mathrm{dx}\,, \qquad \text{and}$$

$$\text{Land Long } P_{UL|E}(E) = \int_{3000}^{\infty} \mathrm{p}_{\mathrm{TSE\_LON|E}}(\mathrm{x},\mathrm{E})\mathrm{dx} \tag{10}$$

Note that this conditional probability is also a function of glide path angle and the fault-free NSE.

A bound on $P_{md}(E)$ for faults that are monitored by the ground facility may be derived from the proposed Annex 10 material since it requires a maximum missed detection probability as a function of range errors, $P_{md\_limit}(|E_R|)$. For example, in the case of the longitudinal touchdown requirement, the vertical position error has the largest effect on the touchdown location. The worst case projection of a range error into vertical error, $max(|S_{Apr\_vert,i}|)$, may be used to determine the resulting limit on $P_{md}(E_v)$ by substituting E_R with $E_v/max(|S_{Apr\_vert,i}|)$ in Equation 3.

$$\max P_{md}(E_v) = P_{md\_\lim it}\left(\frac{E_v}{\max(|S_{Apr\_vert,i}|)}\right) \tag{11}$$

Note that, for a monitor in the airborne equipment, if the actual P_{md} is defined, then that probability, rather than the ground monitor P_{md} limit, may be combined with the airplane performance for the airworthiness determination and to determine geometry screening requirements. Since the unsuccessful landing probability and airborne monitor performance can both be known by the system integrator and shown to meet airworthiness requirements in combination, the airborne monitor does not necessarily need to meet the ground monitor P_{md} limit. The monitor does not even necessarily need to be defined in the range domain.

Note also that anomalous ionosphere errors may be considered an environmental effect, in which case they would be addressed in a manner similar to that for wind conditions and their effect on TSE. Any ground monitoring that might detect or mitigate anomalous ionosphere errors (such as the Code-Carrier Divergence monitoring) is considered as only one piece of the monitoring and is not required to bound the errors according to the P_{md} requirement. The airplane manufacturer could demonstrate that the combination of ground reference and airplane response to anomalous ionosphere events is sufficient to meet the limit condition requirements.

Both types of airborne geometry screening, alert limits and projection factor limits, may be useful as means for meeting the limit case requirement since smaller alert limits will effectively reduce the fault-free NSE that contributes to P_{UL}, and limits on projection factors can reduce the impact of a ranging error in the position domain axis of most concern. For example, a limit may be imposed on the projection, $|S_{Apr\_vert,i}|$, from the range to vertical position domain in order to reduce the probability that a vertical error will go undetected.

Figure J-2 notionally illustrates one method to determine geometry screening parameters based on the longitudinal land short case. In this example lateral errors are assumed to have no impact on the longitudinal touchdown distribution for this airplane design. Example unsuccessful landing probability curves are shown to have been derived using two different assumptions for nominal NSE, VAL=10, 8, and 6. These curves are purposefully chosen to be based on no particular assumptions on touchdown distribution to help illustrate the point that they will be determined for an airplane design based on whatever the airplane response is to NSE errors. Another set of curves represents limits on unsuccessful landing probability, $\max P_{UL}(|E_V|)$ from equation (11), divided by the 10^{-5} limit condition requirement for the land short condition using various choices for $\max|S_{Apr\_vert,i}|$. Any combination that results in $P_{UL}(|E_V|) < \max P_{UL}(|E_V|)$ will satisfy the requirement; however, the combination that provides the highest system availability may be the preferred choice.

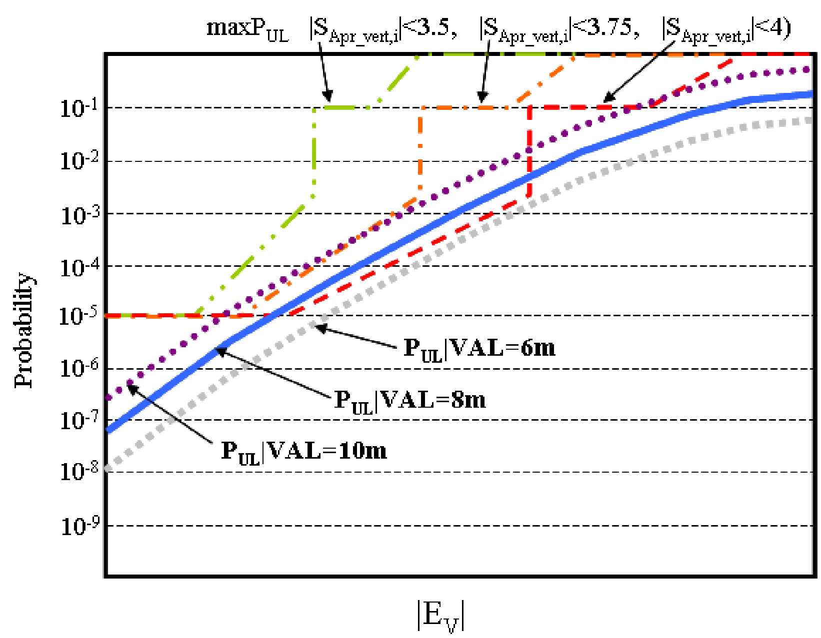

Figure J-2 **Notional Examples of Unsuccessful Landing Probability for a Particular Airplane Design as a Function of Three Alert Limit Choices Compared with Maximum Unsuccessful Landing Probability Based On Ground Monitor P_{md} Requirement Scaled by Three Choices for Projection Factor Screening**

Airplane design and/or geometry screening should also take into account the glidepath angles that are intended for use since the touchdown distribution will also be a function of glide path angle. Smaller glide path angles will change the touchdown dispersion and may cause the P_{UL} to increase. An effect of glide path angle may be that the limit condition (and other conditions) requirement is exceeded for some critical glide path angle. In this case the design should accommodate all glide path angles that are desired for operational approval.

J.2.4 Malfunction Condition

Assume the malfunction condition, briefly summarized, requires the following: Given any error resulting from a malfunction that is more probable than 10^{-9}, and all other varying parameters are at their nominal value, including fault free NSE, the probability of landing in the touchdown box must be one. Consistent with current practice, the definition of "nominal value" should be determined as part of the airworthiness approval process for a particular airplane design.

For the malfunction condition, the Annex 10 derivation requires that all ranging source malfunctions that cause range errors greater than 1.8 meters must be less probable than 10^{-9} after monitoring, when combined with the prior probability of that fault.

For the malfunction case the airborne design may include geometry screening in order to meet this requirement. A limit on the projection of the maximum range error into the position domain, $max(|S_{Apr\_vert,i}|)$, would result in more margin for fault-free NSE and FTE. Also, a reduction in VAL might be used to help an airborne design meet this condition since the fault free NSE must be considered. By choosing a smaller VAL, the nominal TSE may be reduced to accommodate larger errors that are more probable than 10^{-9}.

Once again, airplane design and/or geometry screening should consider the glidepath angles that are intended for use since the touchdown distribution will also be a function of glidepath angle. Smaller glide path angles will change the touchdown dispersion and may cause the P_{UL} to increase, which will cause the limit condition (and other conditions) to be exceeded for some critical glide path.