

Cir 322
AN/184



Guidelines for the Implementation of GNSS Lateral Separation Minima based on VOR Separation Minima

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Published in separate English, Arabic, Chinese, French, Russian
and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 University Street, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

***Cir 322, Guidelines for the Implementation of GNSS Lateral Separation Minima
based on VOR Separation Minima***

Order Number: CIR 322

ISBN 978-92-9249-492-6

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ABBREVIATIONS AND ACRONYMS

AIC	Aeronautical information circular
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information service
ANSP	Air navigation service provider
ATC	Air traffic control
ATS	Air traffic services
CPDLC	Controller-pilot data link communications
DCPC	Direct controller pilot communications
DME	Distance measuring equipment
FAA	Federal Aviation Administration
FD	Fault detection
FDE	Fault detection and exclusion
FL	Flight level
FMS	Flight management system
GLONASS	Global navigation satellite system
GNSS	Global navigation satellite system
GPS	Global positioning system
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
km	Kilometre
m	Metre
NAVAIDS	Navigation aids
NDB	Non-directional beacon
NM	Nautical mile
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management
PBN	Performance-based navigation
RAIM	Receiver autonomous integrity monitoring
RLS	Reference level of safety
RNAV	Area navigation
RNP	Required navigation performance
SASP	Separation and Airspace Safety Panel
SASP-WG/WHL	SASP Meeting of the Working Group of the Whole
SBAS	Space-based augmentation system
SLOP	Strategic lateral offset procedures
TSO	Technical standard order
VHF	Very high frequency
VOR	VHF omnidirectional radio range
WGS-84	World Geodetic System – 1984

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Chapter 1

INTRODUCTION

1.1 PURPOSE

1.1.1 The purpose of this circular is to provide guidance on applying the global navigation satellite system (GNSS) lateral separation minima which is based on the VHF omnidirectional radio range (VOR) lateral separation minima. It is aimed at a worldwide audience within the civil aviation authorities responsible for implementing this and other separation minima.

1.1.2 As a result of the large number of aircraft equipped with instrument flight rules (IFR) GNSS equipment for navigation and its potential use for separation in the procedural environment, the Separation and Airspace Safety Panel (SASP) developed the separation minima detailed in this document for interim use in the transition period to widespread implementation of performance-based navigation (PBN). These separation minima are intended to exploit the capabilities and precision of GNSS equipment that, as a minimum, meet the requirements of ICAO Annex 10 — *Aeronautical Communications*, Volume I — *Radio Navigation Aids*.

1.2 BACKGROUND

1.2.1 In 1996, the International Civil Aviation Organization (ICAO) endorsed the development and use of GNSS as a primary source of future navigation for civil aviation. ICAO noted the increased flight safety, route flexibility and operational efficiencies that could be realized from the move to space-based navigation. Since then, air navigation service providers (ANSPs), airline operators and avionics manufacturers have engaged in an ambitious effort to develop GNSS, their related augmentation systems, airborne receivers and ground infrastructure, and to implement procedures, equip aircraft and train pilots in the use of satellite navigation.

1.2.2 GNSS provides significant improvements when compared to conventional radio navigation installations because of the global availability and accuracy of the GNSS signal. The potential for the use of GNSS for the application of separation was identified in 2002. The first GNSS longitudinal separation was published in November 2007, and the GNSS lateral separation minima introduced in this circular are the second to be published.

1.2.3 This circular is published in support of Amendment No. 6 to the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) which becomes applicable in November 2014.

Chapter 2

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

2.1 INTRODUCTION

2.1.1 This chapter provides a high-level overview of GNSS positioning in the context of using GNSS as a basis for separation in a procedural environment. The information is primarily based on that published in the ICAO *Global Navigation Satellite System (GNSS) Manual* (Doc 9849).

2.1.2 GNSS is global in scope and fundamentally different from traditional navigation aids (NAVAIDs). It has the potential to support all phases of flight, resulting in a seamless global navigation guidance system. GNSS provides accurate guidance in remote and oceanic areas where it is impractical, too costly, or impossible to install traditional NAVAIDs. It also guarantees that all operations are based on a common navigation reference.

2.2 GNSS CORE CONSTELLATIONS AND POSITIONING

2.2.1 Currently, there are two fully operational global satellite constellations in operation: the global positioning system (GPS) provided by the United States and the Russian Global Navigation Satellites System (GLONASS). The European Galileo system is currently under development. These systems will provide independent capabilities but could be used in combination in the future with specifically designed receivers to improve GNSS robustness.

2.2.2 Satellites in the core constellations broadcast a timing signal and a data message that include their orbital parameters (ephemeris data). The GNSS receiver computes position, velocity, time and possibly other information depending on the application. Measurements from a minimum of four satellites are required to establish three-dimensional position (longitude, latitude and height). Accuracy is dependent on the precision of the time measurements from the satellites and the relative geometry of the satellites used. Once the receiver knows its position, it can provide guidance (navigation) between waypoints selected from a database in the receiver. Guidance to a pilot is typically provided through both traditional course deviation indicators and moving map displays. To meet the performance criteria for aviation, GNSS must be able to ensure integrity, accuracy, availability and continuity to specified levels.

2.3 GNSS ACCURACY

2.3.1 GNSS offers position measurements that are equal to or more accurate than distance measuring equipment (DME), VOR and non-directional radio beacon (NDB). The collision risk calculations done to establish the GNSS lateral separation referred to in this circular assumed the GNSS along-track accuracy to be ± 0.124 NM, GNSS cross-track accuracy to be ± 1 NM, DME Fix Tolerance to be ± 0.25 NM plus 1.25 per cent of the distance to the antenna, VOR accuracy to be ± 1 NM and ± 5.2 degrees, and NDB accuracy to be ± 1 NM and ± 6.9 degrees. All of those were assumed to be 95th percentile containment values.

2.3.2 In addition to a high degree of accuracy, GNSS receivers approved for IFR operations offer integrity by providing alerts when the position cannot be guaranteed within a specified degree of certainty. These alert limits are:

- a) en-route – 3.7 km (2.0 NM);
- b) terminal – 1.85 km (1.0 NM); and
- c) approach – 556 m (0.3 NM).

2.3.3 The position information provided by the GNSS to the user is expressed in terms of the World Geodetic System – 1984 (WGS-84) geodetic reference datum.

2.4 GNSS LATERAL SEPARATION MINIMA

This circular addresses the implementation of the following GNSS lateral separation minima published in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), paragraph 5.4.1.2.1.2.

5.4.1.2 Lateral separation criteria and minima

5.4.1.2.1 Means by which lateral separation may be applied include the following:

5.4.1.2.1.1 *By reference to the same or different geographic locations.* By position reports which positively indicate the aircraft are over different geographic locations as determined visually or by reference to a navigation aid (see Figure 5-3).

5.4.1.2.1.2 *By use of NDB, VOR and GNSS on intersecting tracks or ATS routes.* By requiring aircraft to fly on specified tracks which are separated by a minimum amount appropriate to the navigation aid employed. Lateral separation between two aircraft exists when:

- a) *VOR*: both aircraft are established on radials diverging by at least 15 degrees and at least one aircraft is at a distance of 28 km (15 NM) or more from the facility (see Figure 5-4);
- b) *NDB*: both aircraft are established on tracks to or from the NDB which are diverging by at least 30 degrees and at least one aircraft is at a distance of 28 km (15 NM) or more from the facility (see Figure 5-5);
- c) *GNSS/GNSS*: each aircraft is confirmed to be established on a track with zero offset between two waypoints and at least one aircraft is at a minimum distance from a common point as specified in Table 5-1; or
- d) *VOR/GNSS*: the aircraft using VOR is established on a radial to or from the VOR and the other aircraft using GNSS is confirmed to be established on a track with zero offset between two waypoints and at least one aircraft is at a minimum distance from a common point as specified in Table 5-1.

Table 5-1

	Aircraft 1: VOR or GNSS Aircraft 2: GNSS	
Angular difference between tracks measured at the common point	FL010 — FL190 Distance from a common point	FL200 — FL600 Distance from a common point
15 – 135	27.8 km (15 NM)	43 km (23 NM)
The distances in the table are ground distances. States must take into account the distance (slant range) from the source of a DME signal to the receiving antenna when DME is being utilized to provide range information.		

Note 1.— The values in the table above are from a larger table of values derived by collision risk analysis. The source table for separation of aircraft navigating by means of GNSS and VOR is contained in Circular 322, Guidelines for the Implementation of GNSS Lateral Separation Minima Based on VOR Separation Minima. States may refer to Circular 322 for greater detail and other angular differences and separation distances.

Note 2.— The values in the table above have accounted for distances from the common point encompassed by the theoretical turn area for fly-by turns as specified in the Minimum Aviation System Performance Standard: Required Navigation Performance for Air Navigation (ED-75B/DO-236B), section 3.2.5.4 and fixed radius transition turns as defined in the Performance-based Navigation (PBN) Manual (Doc 9613).

Note 3.— Guidance material for the implementation of the GNSS lateral separation is contained in Circular 322.

5.4.1.2.1.2.1 When aircraft are operating on tracks which are separated by considerably more than the minimum figures in 5.4.1.2.1.2 a) and b), States may reduce the distance at which lateral separation is achieved.

5.4.1.2.1.2.2 Before applying GNSS-based track separation the controller shall confirm the following:

- a) ensure that the aircraft is navigating using GNSS; and
- b) in airspace where strategic lateral offsets are authorized, ensure that a lateral offset is not being applied.

5.4.1.2.1.2.3 In order to minimize the possibility of operational errors, waypoints contained in the navigation database or uplinked to the aircraft flight management system should be used in lieu of manually entered waypoints, when applying GNSS-based track separation. In the event that it is operationally restrictive to use waypoints contained in the navigation database, the use of waypoints that require manual entry by flight crews should be limited to half or whole degree of latitude and longitude.

5.4.1.2.1.2.4 GNSS-based track separation shall not be applied in cases of pilot reported receiver autonomous integrity monitoring (RAIM) outages.

Note.— For the purpose of applying GNSS-based lateral separation minima, distance and track information derived from an integrated navigation system incorporating GNSS input is regarded as equivalent to GNSS distance and track.

5.4.1.2.1.2.5 GNSS receivers used for applying separation shall meet the requirements in Annex 10, Volume I, and be indicated in the flight plan.

2.5 GNSS TERMINOLOGY

2.5.1 Receiver Autonomous Integrity Monitoring (RAIM) — RAIM provides integrity monitoring of GPS for aviation applications. In order for a GPS receiver to perform RAIM or fault detection (FD) function, a minimum of five satellites with satisfactory geometry must be visible to it. The RAIM function performs consistency checks between position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if the consistency checks fail. Because of geometry and service maintenance RAIM is not always available.

2.5.2 Fault Detection and Exclusion (FDE) — An enhanced version of RAIM employed in some receivers is known as fault detection and exclusion (FDE). It uses a minimum of six satellites to not only detect a possibly faulty satellite, but to exclude it from the navigation solution so the navigation function can continue without interruption. The goal of fault detection is to detect the presence of a positioning failure. Upon detection, proper fault exclusion determines and excludes the source of the failure (without necessarily identifying the individual source causing the problem), thereby allowing GNSS navigation to continue without interruption. Availability of RAIM and FDE will be slightly lower for mid-latitude operations and slightly higher for equatorial and high-latitude regions due to the nature of the orbits. The use of satellites from multiple GNSS constellations or the use of space-based augmentation system (SBAS) satellites as additional ranging sources can improve the availability of RAIM and FDE.

2.5.3 RAIM Prediction — GNSS differs from traditional navigation systems because the satellites and areas of degraded coverage are in constant motion. Therefore, if a satellite fails or is taken out of service for maintenance, it is not immediately clear which areas of the airspace will be affected, if any. The location and duration of these outages can be predicted with the aid of computer analysis. During the pre-flight planning process, pilots should use a RAIM predictive programme to ensure adequate GNSS coverage along the planned route of flight.

2.6 GNSS IMPLEMENTATION ISSUES

2.6.1 In developing the safety assessment for the VOR-like GNSS standard, SASP recognized the importance of a number of factors that would impact on any implementation of the standards on a global basis. Among these factors, two had specific importance in the SASP safety assessment, namely the areas of applicability and equipment eligibility, and are described in detail in the following paragraphs. To resolve any additional safety issues identified when undertaking their own safety assessment, States could consider adding an additional buffer, for example, when one or both aircraft are inbound to the common point to take account of the effect of increased closure rate on risk.

2.6.2 Communication and Area of Applicability — Historically VOR and NDB separation was normally used in areas that were also served with direct controller pilot communication – very high frequency voice communication (DCPC-VHF). Since GNSS provides worldwide coverage, it has the potential to be used where DCPC VHF is not available, such as in oceanic and remote airspace. As part of the implementation process, the appropriate air traffic services (ATS) authority must determine, for each area of application, the communication requirements for the application of the GNSS lateral separation minima. This issue is considered further in Hazard 2 in Attachment B.

2.6.3 Equipment Eligibility — The eligibility for allowing the application of GNSS lateral separation minima to aircraft utilizing integrated area navigation (RNAV) systems incorporating GNSS inputs has also been considered. Discussions regarding this issue involved the analysis of how the various types of flight management system (FMS) work, and whether it could be assumed that position information from integrated RNAV systems incorporating GNSS input could be regarded as equivalent to GNSS position. It was agreed that with over 400 varying FMSs, it would be difficult to speculate how each FMS derived its navigation data. However, after thorough discussion the SASP came to the conclusion that any position report derived from an FMS incorporating GNSS would be acceptable, as it would be more accurate than a VOR/DME position report.

2.6.4 **Implementation Safety Assessment** — In order to ensure that the implementation of GNSS lateral separation minima is safe, the appropriate ATS authority must undertake its own implementation safety assessment as outlined in Chapter 2 of the PANS-ATM. This is to complement the SASP safety assessment to account for possible local conditions that may not have been covered by the safety assessment work of SASP. For this reason, the safety assessment work carried out by the SASP is included in Chapter 3 of this circular. Chapter 4 indicates what remains to be done by the appropriate ATS authority as part of its implementation safety assessment.
