ICAO Radio Navigation Workshop for NAM & SAM Regions

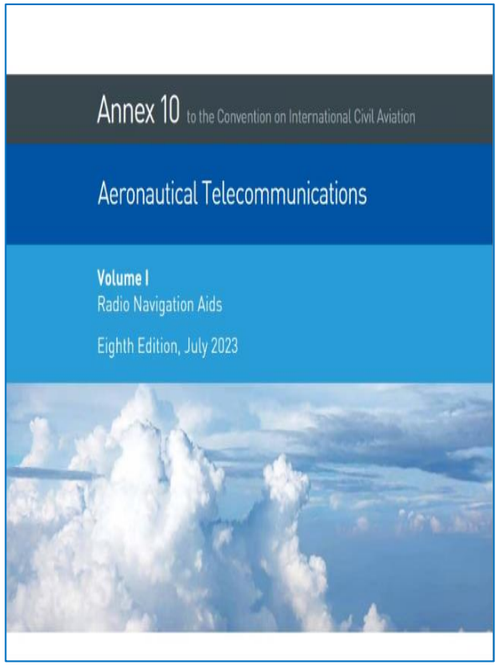
Global Developments and ICAO roadmap to address GNSS RFI

Muna Alnadaf – Technical Officer CNS/ ICAO HQ

Mexico City - Mexico

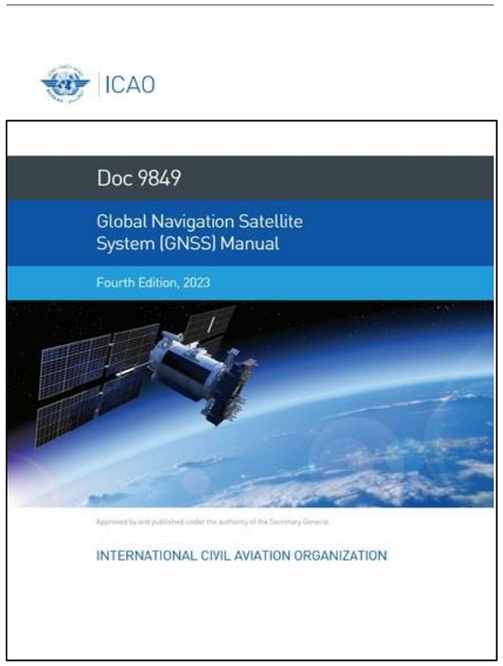
2-4 September 2025

Relevant ICAO Provisions



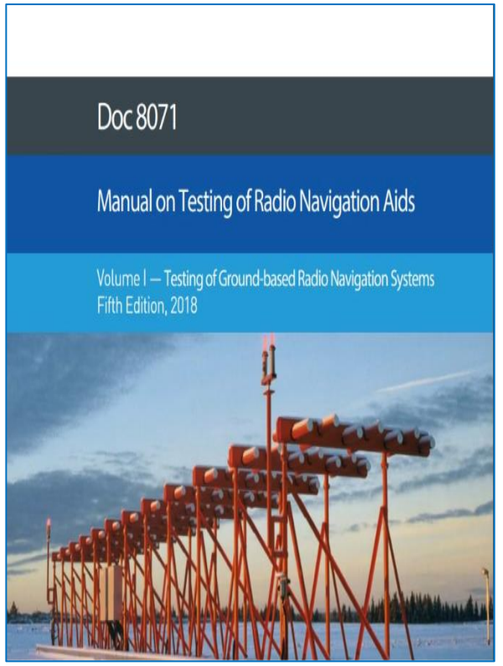
Annex 10, Volume I

Aeronautical Telecommunications:
Radio Navigation Aids



ICAO Doc 9849

Global Navigation Satellite
System (GNSS) Manual



ICAO Doc 8071, Vol I

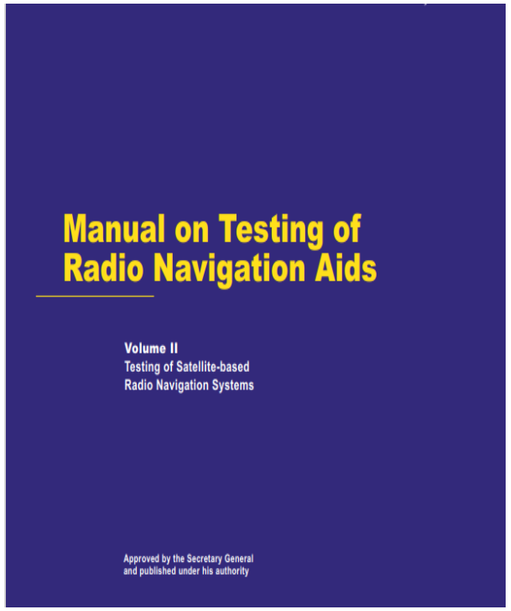
Testing of Ground-based
Radio Navigation Systems

Additional ICAO Provisions

1

ICAO Doc 8071, Vol II

Manual on Testing of Satellite-based Radio Navigation Systems



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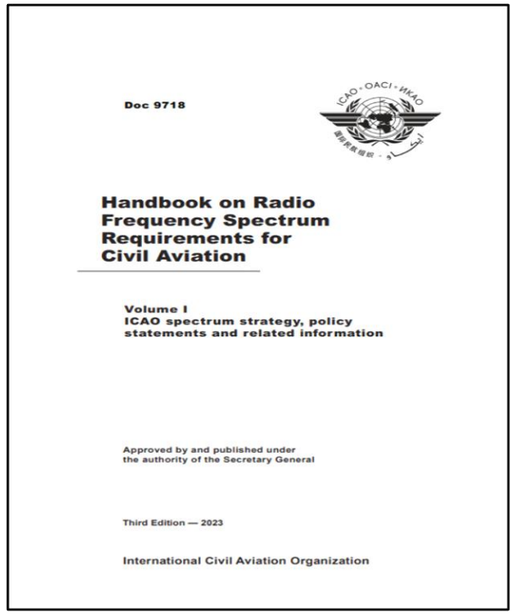
ICAO Doc 9718

Handbook on Radio Frequency Spectrum Requirements for Civil Aviation



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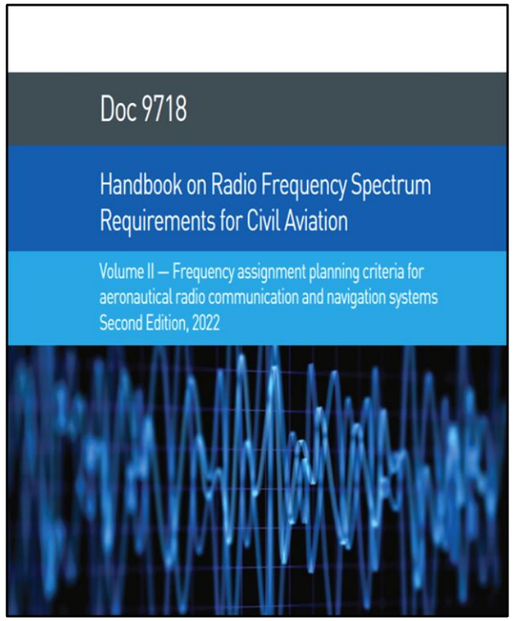
ICAO Doc 9718 Vol II

Frequency Assignment Criteria for Aeronautical Radio Communication & Navigation systems



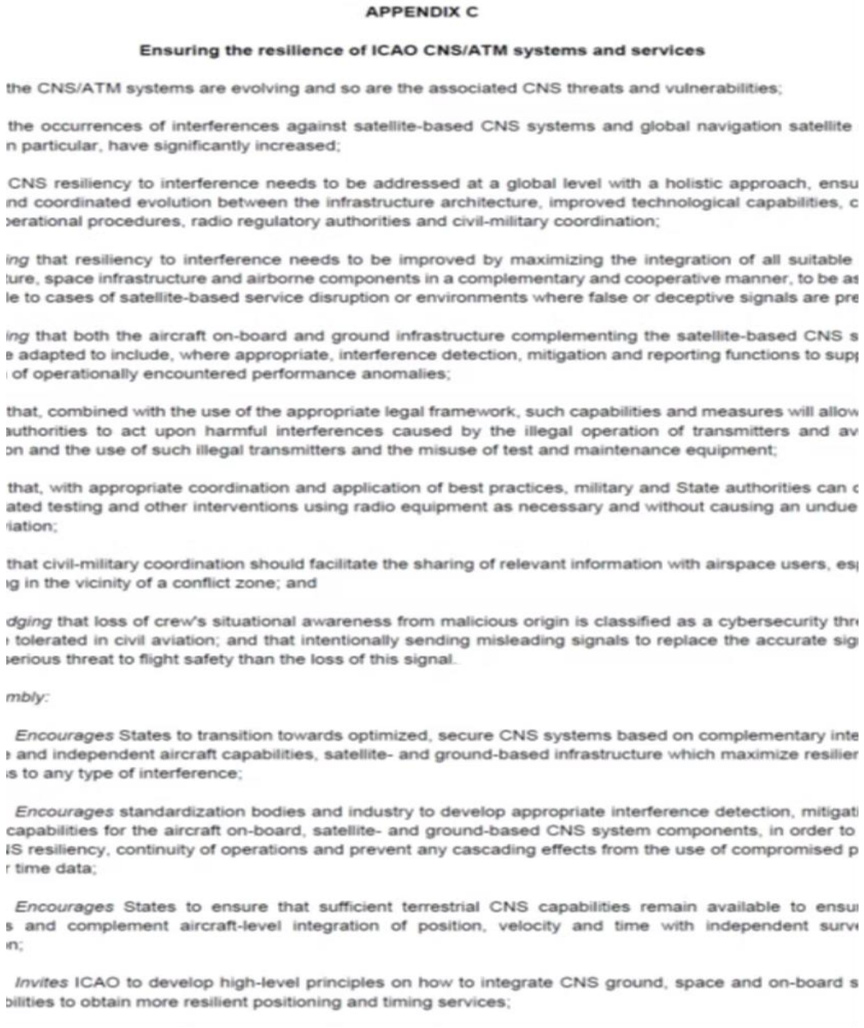
The GNSS RFI Challenge

Loss of Control in-Flight (LOC-I)

Controlled flight into terrain (CFIT)

Mid-air Collision (MAC)

ICAO 41st Assembly Resolution



APPENDIX C

Ensuring the resilience of ICAO CNS/ATM systems and services

the CNS/ATM systems are evolving and so are the associated CNS threats and vulnerabilities;

the occurrences of interferences against satellite-based CNS systems and global navigation satellite
n particular, have significantly increased;

CNS resiliency to interference needs to be addressed at a global level with a holistic approach, ensu
nd coordinated evolution between the infrastructure architecture, improved technological capabilities, c
erational procedures, radio regulatory authorities and civil-military coordination;

ing that resiliency to interference needs to be improved by maximizing the integration of all suitable
ure, space infrastructure and airborne components in a complementary and cooperative manner, to be as
le to cases of satellite-based service disruption or environments where false or deceptive signals are pre

ing that both the aircraft on-board and ground infrastructure complementing the satellite-based CNS s
e adapted to include, where appropriate, interference detection, mitigation and reporting functions to supp
of operationally encountered performance anomalies;

that, combined with the use of the appropriate legal framework, such capabilities and measures will allow
uthorities to act upon harmful interferences caused by the illegal operation of transmitters and av
on and the use of such illegal transmitters and the misuse of test and maintenance equipment;

that, with appropriate coordination and application of best practices, military and State authorities can c
ated testing and other interventions using radio equipment as necessary and without causing an undue
iation;

that civil-military coordination should facilitate the sharing of relevant information with airspace users, esp
g in the vicinity of a conflict zone; and

dging that loss of crew's situational awareness from malicious origin is classified as a cybersecurity thr
tolerated in civil aviation; and that intentionally sending misleading signals to replace the accurate sig
erious threat to flight safety than the loss of this signal.

mbly:

Encourages States to transition towards optimized, secure CNS systems based on complementary inte
and independent aircraft capabilities, satellite- and ground-based infrastructure which maximize resilier
s to any type of interference;

Encourages standardization bodies and industry to develop appropriate interference detection, mitigati
capabilities for the aircraft on-board, satellite- and ground-based CNS system components, in order to
IS resiliency, continuity of operations and prevent any cascading effects from the use of compromised p
time data;

Encourages States to ensure that sufficient terrestrial CNS capabilities remain available to ensu
s and complement aircraft-level integration of position, velocity and time with independent surv
n;

Invites ICAO to develop high-level principles on how to integrate CNS ground, space and on-board s
bilities to obtain more resilient positioning and timing services;

Resolution A41-8, Appendix C

ICAO Policy on GNSS Resilience

The 41st Session of the ICAO Assembly established a comprehensive policy framework addressing:

- Recognition of GNSS as a critical component of modern air navigation
- Requirement for protection from harmful interference
- Need for resilient systems and services
- International cooperation for spectrum protection
- Development of Invites ICAO to develop high-level principles on how to integrate CNS ground, space and on-board systems and capabilities to obtain more resilient positioning and timing services

14th Air Navigation Conference Recommendations

Recommendation 2.2/2 – Addressing GNSS Interference & Contingency Planning

State Responsibilities

- Implement **effective GNSS RFI mitigation measures** based on ICAO and industry guidance
- Maintain **sufficient network of conventional navigation aids** for operational safety
- Develop **regional GNSS reporting procedure** through planning and implementation regional groups (PIRGs)
- Collaborate with industry to make aircraft systems more **resilient to RFI events**
- Review aircraft **minimum equipage lists** to ensure compatibility with implemented minimum operational networks

14th Air Navigation Conference Recommendations (Continued)

Recommendation 2.2/2 – ICAO Responsibilities

ICAO Mandates

- Continue to **assess the impact of GNSS interference** on aviation safety and operations
- Develop a **standardized implementation package** (iPack) to assist States with RFI mitigation measures
- Develop **guidance on GNSS interference information exchange** and **civil-military coordination**
- Develop **recommendations for globally harmonized minimum aircraft equipage lists** to ensure infrastructure compatibility

ICAO EUR/MID Radio Navigation Symposium

International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

Tel.: +1 514-315-1872

30 April 2024

Ref.: E 3/5-24/54

Subject: Aviation safety concerns regarding interference to the Global Navigation Satellite System (GNSS)

Action required: a) disseminate guidance material; and b) implement recommendations, as applicable

Sir/Madam,

1. I have the honour to bring to your attention the concerning escalation of jamming and spoofing activities targeting the global navigation satellite system (GNSS), which have been increasingly observed recently in various regions globally. GNSS, as one of the main enablers for performance-based navigation (PBN), provides navigation guidance for all phases of flight, from enroute through to precision approach. By providing accurate position and timing information, GNSS enables several systems critical to the safety of flight.

2. Since 2003, the International Civil Aviation Organization (ICAO) has been actively developing recommendations and guidance concerning GNSS Radio Frequency Interference (RFI). It is pertinent to recall ICAO Assembly Resolution A41-8, Appendix C: *Ensuring the resilience of ICAO CNS/ATM systems*, which serves as the latest ICAO policy on GNSS resilience.

3. To bring attention to the critical issue of GNSS interference, and to foster discussions on the management of GNSS vulnerabilities and potential mitigation measures against GNSS RFI, ICAO recently convened the ICAO EUR/MID Radion Navigation Symposium from 6 to 8 February 2024 in Antalya, Turkey. One important outcome of this symposium is the attached list of recommendations regarding Stakeholders' continued efforts towards ensuring safe, reliable, and resilient air navigation.

4. I would like to take this opportunity to refer to recent safety-related publications by the European Union Aviation Safety Agency (EASA), Safety Information Bulletin No. 2022-02R2 and the Federal Aviation Administration (FAA), Safety Alert for Operators (SAFO 24002).

February 2024

ICAO organized a specialized symposium focused on GNSS RFI challenges in the European and Middle Eastern regions, which are particularly affected by interference incidents.

A State Letter dated April 30, 2024, circulated these outcomes and requested States to implement the recommendations as applicable to their operations.

Electronic Bulletin

Disseminated the OPSGroup Report for information & awareness (EB 2024/27)

International Civil Aviation Organization

ELECTRONIC BULLETIN

For information only

EB 2024/27 — 18 December 2024

REPORT OF THE OPSGROUP GPS SPOOFING WORKGROUP

1. On 4 November 2024, the Council of the International Civil Aviation Organization (ICAO) was briefed on a report providing the outcomes of an impact assessment on Global Positioning System (GPS) Spoofing, developed by a Working Group of the OPSGROUP. Membership of the OPSGROUP consists primarily of pilots, flight dispatchers, schedulers and controllers. The report provides comprehensive information on the recent increase in GPS Spoofing incidents, their operational impact and various safety concerns.

2. On 5 November 2024, the Council in its 7th meeting of the 233rd session reiterated its serious concerns regarding the impact of interference to the Global Navigation Satellite Systems (GNSS) on the safety and security of air navigation systems, particularly as such occurrences are expected to increase, posing an ever-growing safety hazard to global flight operations. Consequently, the Council has requested (C-DEC 233/7) that the attached report be circulated amongst Member States and relevant industry stakeholders.

3. The Report of the OPSGROUP GPS Spoofing Workgroup, which was published on 6 September 2024, includes detailed analysis of the technical background, impacts to aircraft handling and operation, best practices for flight crew, and a series of safety concerns and recommendations for industry attention.

4. The Report of the OPSGROUP is herewith attached for information and awareness of Member States and industry stakeholders.

Enclosure:
GPS-Spoofing-Final-Report-OPSGROUP-WG-OG24 (English only)

Issued under the authority of the Secretary General

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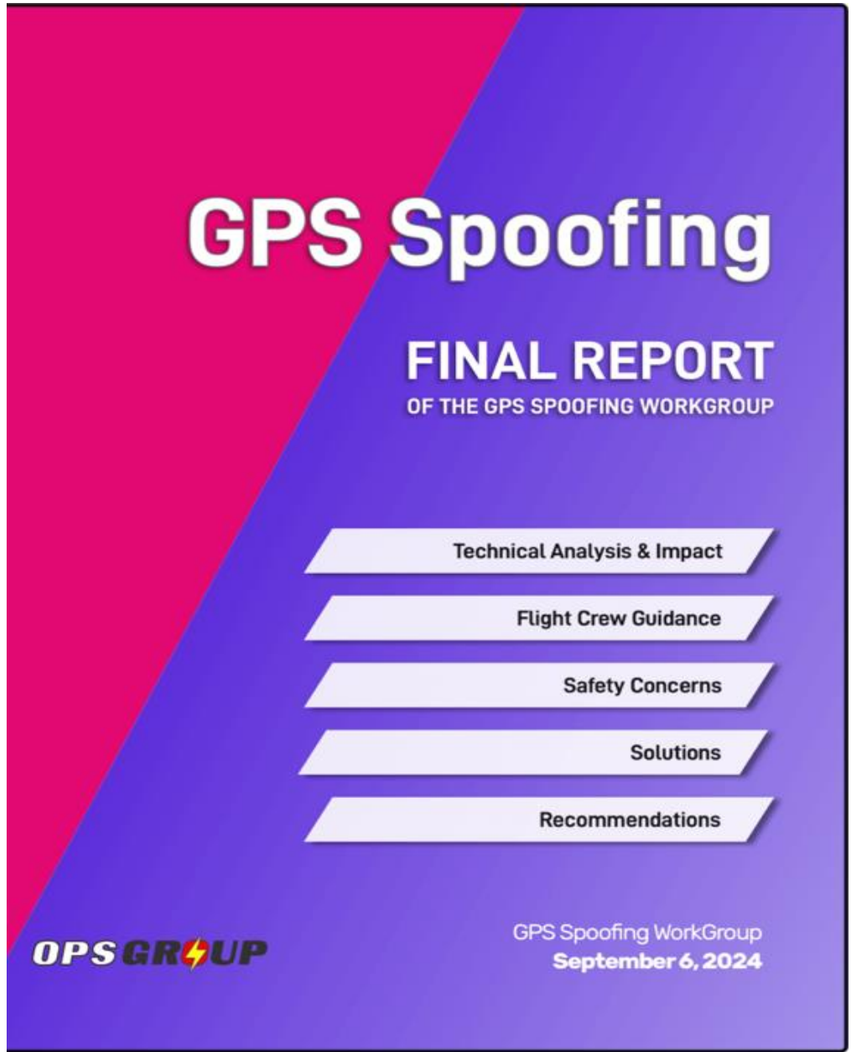
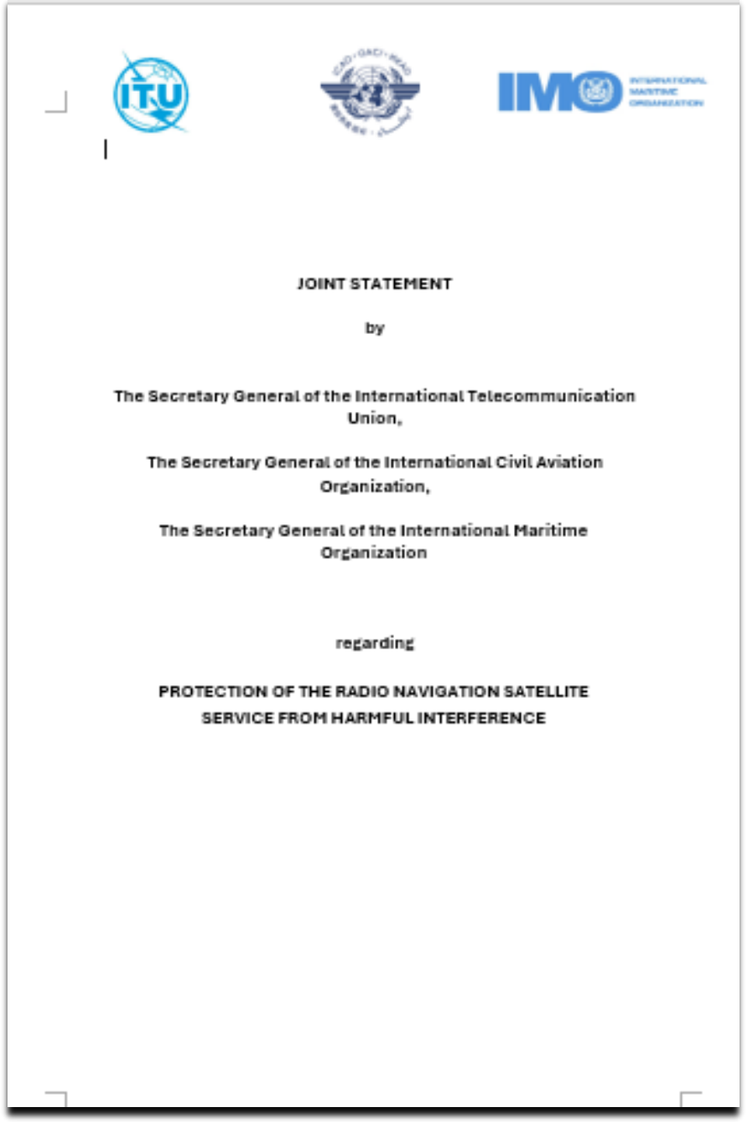
ICAO

OPSGroup Report

Issued September, 2024





JOINT STATEMENT

by

The Secretary General of the International Telecommunication Union,

The Secretary General of the International Civil Aviation Organization,

The Secretary General of the International Maritime Organization

regarding

PROTECTION OF THE RADIO NAVIGATION SATELLITE SERVICE FROM HARMFUL INTERFERENCE

Joint Statement by ITU, ICAO, & IMO regarding the protection of Radio Navigation Satellite System (RNSS) from harmful interference

Key Elements of the Joint Statement

ICAO

Protect RNSS

Protect Radio Navigation Satellite Systems from transmissions that can adversely cause harmful interference degrading, interrupting or misleading signals used for civilian and humanitarian purposes

Reinforce Resilience

Strengthen the resilience of systems which rely on RNSS for navigation, positioning and timing in relation to interference

Retain Infrastructure

Maintain sufficient conventional navigation infrastructure for contingency support during RNSS outages and develop mitigation techniques

Increase Collaboration

Enhance cooperation between radio regulatory, civil aviation, maritime, defense and enforcement authorities

Report Interference

Report cases of harmful interference affecting RNSS to appropriate authorities and to the ITU Radiocommunications Bureau for monitoring

These five pillars form a comprehensive framework for international action to protect GNSS services across sectors.

Amendment 94 of Annex 10 Volume I

International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

Tel.: +1 514-315-1872

Ref.: AN 7/62.2.4-25/31

24 April 2025

Subject: Adoption of Amendment 94 to Annex 10, Volume I

Action required: a) Notify any disapproval before 4 August 2025, b) Notify any differences and compliance before 27 October 2025; c) Consider the use of the Electronic Filing of Differences (EFOD) System for notification of differences and compliance

Sir/Madam,

1. I have the honour to inform you that Amendment 94 to the *International Standards and Recommended Practices, Aeronautical Telecommunications — Radio Navigation Aids* (Annex 10, Volume I to the Convention on International Civil Aviation) was adopted by the Council at the twelfth meeting of its 234th Session on 28 March 2025. Copies of the Amendment and the Resolution of Adoption are available as attachments to the electronic version of this State letter on the ICAO-NET (http://portal.icao.int) where you can access all other relevant documentation.

2. When adopting the amendment, the Council prescribed 4 August 2025 as the date on which it will become effective, except for any part concerning which a majority of Contracting States have registered their disapproval before that date. In addition, the Council resolved that Amendment 94, to the extent it becomes effective, will become applicable on 27 November 2025.

3. Amendment 94 arises from recommendations of the seventh meeting of the Navigation Systems Panel (NSP/7). The amendment concerns advanced receiver autonomous integrity monitoring (ARAIM), the global positioning system (GPS), the Galileo system, the satellite-based augmentation system (SBAS), the ground-based augmentation system (GBAS), distance-measuring equipment (DME) and frequency assignment planning for instrument landing system (ILS), VHF omnidirectional radio range (VOR), DME and GBAS.

4. The amendment concerning advanced receiver autonomous integrity monitoring (ARAIM) introduces ARAIM Service Type A ("Horizontal ARAIM" (H-ARAIM)), which supports horizontal positioning for typical operations of en-route through initial approach, intermediate approach, non-precision approach and departure. ARAIM supports the use of dual-frequency, multi-constellation (DFMC) GNSS with the associated benefits in terms of navigation performance and robustness.

Key Regulatory Update

1- Introduces ARAIM Service Type A ("Horizontal ARAIM" (H-ARAIM)), which supports horizontal positioning for typical operations of en-route through initial approach, intermediate approach, non-precision approach and departure. ARAIM supports the use of DFMC GNSS with the associated benefits in terms of navigation performance and robustness.

2- Addresses some inconsistencies regarding GPS, GALILEO and SBAS

3- introduce guidance material for the determination of the certain tropospheric parameters transmitted by GBAS ground equipment in Type 2 messages

4- addresses coverage requirements for DMEs that are not associated with VOR, ILS or MLS to support PBN implementation

5- relocation of the guidance material regarding frequency assignment planning and utilization criteria from Annex 10, Vol I to ICAO doc 9718

ICAO's Short-Term Actions

Regional Activities

- Workshops and symposia to raise awareness
- Gathering participants from Member States and international organizations
- Exchange of insights and best practices

GNSS RFI-related NOTAM Standardization

- Currently, 18 different NOTAM codes are used worldwide, creating operational challenges
- Two standardized codes for interference and spoofing and recommended Item E text are being developed
- Guidance on NOTAM interpretation for pilots is under development

Joint Statement with ITU and IMO

- Protecting GNSS from harmful interference
- Call for stronger system resilience across sectors
- Maintaining conventional navigation infrastructure as backup

Enhanced Reporting Mechanisms

- Improved access to ITU's Satellite Interference Reporting and Resolution System (SIRRS)
- Guidance for regional reporting through SIRRS to be finalized by Q4 2025

Reporting GNSS RFI to ITU

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Space Services Department

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SIRRS

Satellite Interference Reporting and Resolution System

- As per Resolutin 55 (Rev. WRC-23) Reports of Harmful Interference affecting Space Services are to be submitted by SIRRS -

This online application has been developed by the Radiocommunication Bureau in response to Resolution 186 of ITU Plenipotentiary Conference 2014 with the aim to facilitate Administrations and space stakeholders to report a case of harmful interference affecting space services, to request assistance from the BR, to be informed in case a radio station under your jurisdiction is causing harmful interference to space services of other Administrations, and to exchange all necessary information among the concened parties involved in the case.

In order to be able to use the system, a user account must be open as indicated below:

Reporting

(ITU Registered Users)

LOGIN I forgot my password...

References:

Short Video to Use SIRRS

Implementation Package (iPack) for GNSS RFI Mitigation

Raise Awareness

Educate stakeholders on effects of GNSS RFI on CNS/ATM systems, aviation operations, and GNSS-based services through comprehensive training materials and workshops

Risk Mitigation Framework

Provide methodologies for threat monitoring, risk assessment, and implementation of mitigation measures tailored to specific operational environments

Expert Support

Deliver hands-on guidance to develop essential policies, procedures, and training requirements for managing GNSS RFI events

Infrastructure Assessment

Assist States in assessing conventional navigation infrastructure for a rationalized approach to maintaining necessary backup capabilities

The iPack is scheduled to be completed in Q4 2025, providing States with a comprehensive toolkit for addressing GNSS RFI challenges.

Complementary PNT (C-PNT)

Assembly Resolution A41-8 emphasizes the need for enhancing resilience to interference by maximizing the integration of all suitable infrastructure components.

Multi-Sensor Integration

Improve integration between space-based, ground-based, and airborne capabilities

Ensure individual airborne systems cannot corrupt others

Balanced Capabilities

Achieve suitable balance between terrestrial, aircraft autonomous capabilities (INS and other sensors), and space-based capabilities

Precise Time Sources

Introduce GNSS-independent time sources to enhance integrity of air and ground systems

C-PNT related provisions are expected to be completed by 2030, requiring industry commitment and support from all stakeholders

Resilient Navigation Operational Network (NAV RON)

- ✓ The RON concept evolves from the navigation minimal operational network (NAV MON) to ensure operational safety and continuity during GNSS RFI
- ✓ Provide guidance to States towards achieving sustainable, cost-effective navigation capabilities
- ✓ Better utilize combinations of available conventional terrestrial navigation aids (VOR, DME, ILS, NDB) to support GNSS reversion during disruptions:
  1) as redundant aids to support PBN navigation specifications and enable cross-check with GNSS
  2) as contingency support to facilitate pilot positional awareness and/or
  3) as already well established, as infrastructure for conventional Instrument Flight Procedures (IFP).
- ✓ Optimize deployment of terrestrial navigation aids based on traffic density, operational requirements, and aircraft capabilities
- ✓ Aeronautical digital data and charts should be improved, to better inform pilots about the existing conventional navigation facilities, including its type and coverage, and ensure that aircrew and aircraft can make maximum use of such infrastructure.

Timeline of ICAO's GNSS RFI Initiatives

1

2025 Q4

- Finalization of regional reporting guidance through SIRRS
- Launch of iPack implementation phase

2

2027 November

Validation of SARPs for SBAS Authentication feature finalized

3

2029

SARPs for Galileo OSNMA navigation data authentication applicable

4

2030

Completion of Complementary PNT (C-PNT) actions

5

2032-2035

Initial operational introduction of DFMC GNSS

Dual Frequency Multiple Constellations (DFMC) GNSS

Enhanced Global Navigation

Utilizes signals from multiple satellite constellations: GPS, Galileo, GLONASS, and BeiDou

Improves accuracy, reliability, and resilience against interference compared to single-frequency systems

Mitigating Vulnerabilities

Addresses RFI affecting a single frequency or constellation

Reduces impact of ionospheric disturbances

Minimizes risk of having insufficient satellites within a single constellation

Implementation Timeline

Amendment 93 to Annex 10, Volume I introduced provisions to support DFMC GNSS

Initial operational introduction expected in the 2032-2035 timeframe

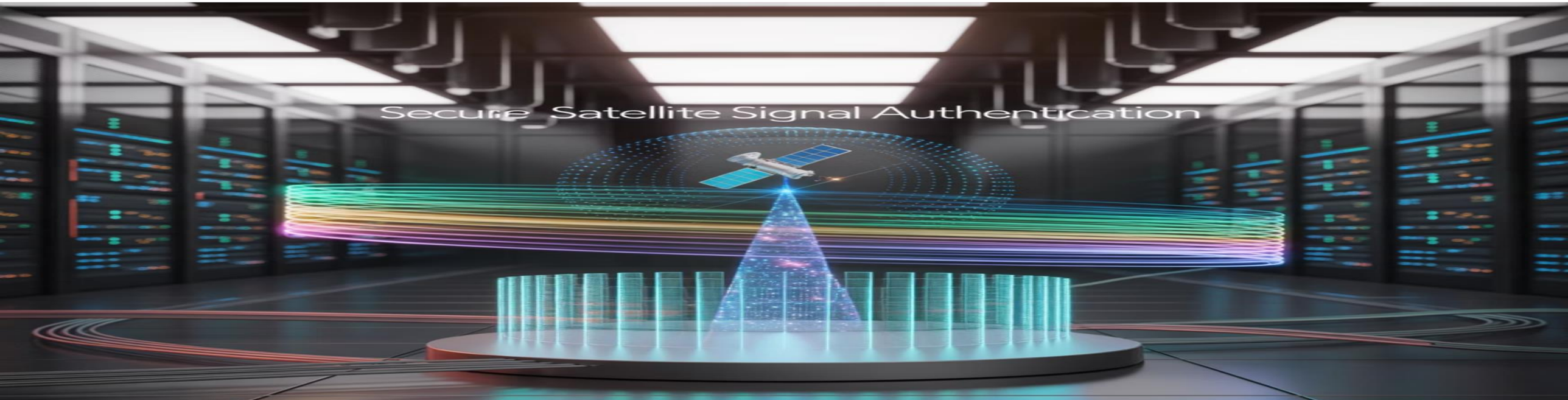
Authentication Solutions

Galileo Open Service Navigation Message Authentication (OSNMA)

- Ensures received navigation message genuinely originates from Galileo satellites
- Adds an additional security layer
- SARPs for Galileo OSNMA expected to be applicable in 2029

SBAS Authentication

- Current SBAS signals are unencrypted and vulnerable to falsification
- ICAO started development of SARPs for SBAS Authentication in 2017
- Validation of SARPs for the optional new authentication feature expected to be finalized in November 2027



GNSS Interference Monitoring

Many stakeholders have expressed the need for improved situational awareness of GNSS RFI impacted areas, both on the flight deck and in air traffic control rooms.

Concept of Operation

ICAO NSP in collaboration with SP are developing a concept to outline how RFI monitoring capabilities can better support operational decision-making

Operational Support

Goal is to help maintain safe and efficient air traffic management in an evolving GNSS RFI environment

Data Standardization

Standardization of associated data exchange formats is being considered to ensure consistent information sharing

Key Takeaways

1

GNSS RFI is a Significant Safety Risk

Can lead to critical systems failures with potential for mid-air collision, controlled flight into terrain, and loss of control in-flight

2

Multi-Layered Approach

ICAO has developed comprehensive approach, short, medium, and long-term actions to address immediate concerns while building long-term resilience through technological improvement and international cooperation

3

Technological Solutions

C-PNT, DFMC GNSS, authentication protocols, and other advanced onboard technologies will significantly enhance resiliency and improve defenses against GNSS RFI

4

Global Cooperation Required

Success depends on collaboration between ICAO, international organizations, States, industry and all other stakeholders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Thank You!