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Agenda Item 5.7: CNS

**GNSS PERFORMANCE MONITORING AND DME-TO-DME OPTIMIZATION SUPPORTING
THE RESILIENT NAVIGATION OPERATIONAL NETWORK (RON)**

(Presented by Saudi Arabia)

SUMMARY

This paper presents an integrated, two-layered approach to NAV MON resilience within Jeddah FIR. First, it describes the GNSS Performance Monitoring System (GPMS) deployed by Saudi Air Navigation Services (SANS) to increase the situational awareness for ATCOs, ATSEPs, and flight crews. Second, it discusses how optimizing Distance Measuring Equipment (DME) through DME-to-DME coverage and adopting omnidirectional antennas provide the resilient terrestrial reversion capability needed to ensure continuous, safe Positioning, Navigation and Timing (PNT). Together, monitoring and DME-to-DME coverage form a robust, layered, multi-source navigation architecture that aligns with the ICAO Resilient Navigation Operational Network (RON) concept and reduces the impact of GNSS unavailability or RFI.

Challenges and considerations for implementation are also reviewed to contribute to ICAO and MID Region efforts to establish the Resilient Navigation Operational Network (RON).

Action by the meeting is at paragraph 6.

REFERENCES

- ICAO Annex 10, Volume VI — Aeronautical Telecommunications.
- Doc 9613, Performance-Based Navigation (PBN) Manual.
- Doc 9849, Global Navigation Satellite System (GNSS) Manual.
- Doc 10222, A42-TE, Technical Commission Report.
- Assembly Resolution A42-8 (formerly A41-8), Appendix C — Ensuring the resilience of ICAO CNS/ATM systems and services.
- Doc 10209, AN-Conf/14, Fourteenth Air Navigation Conference Report, Recommendation 2.2/2 — Addressing GNSS Interference and Contingency Planning.
- ICAO GNSS RFI Roadmap — Medium-Term Actions (2027–2029) (www.icao.int/air-navigation-bureau/gnss-rfi/roadmap/medium-term-actions).
- MIDANPIRG Decision 22/20 — MID NAV-MON Action Group;
- MIDANPIRG/22–RASG/12 Conclusions 2 and 4.

1. INTRODUCTION

1.1 GNSS is a fundamental enabler of modern aviation, supporting navigation, surveillance and timing functions, including PBN and ADS-B operations. Over time, civil aviation has become increasingly reliant on GNSS for precise positioning, navigation and timing (PNT).

1.2 However, GNSS signals are inherently weak at the receiver, making them highly susceptible to interference from both intentional and unintentional sources. GNSS RFI comes mainly in two forms: jamming, which prevents reception of GNSS signals, and spoofing, which transmits deceptive GNSS-like signals that mislead avionics into computing incorrect time and/or position.

1.3 The 42nd Session of the ICAO Assembly (A42) recognized, through working paper A42-WP/34 and the adoption of Assembly Resolution A42-8, Appendix C, that GNSS RFI has become a major global safety risk that must be addressed through a coordinated, multi-layered strategy combining technical, operational, regulatory and strategic measures. GNSS RFI has been identified as a contributor to three global high-risk categories of occurrence: mid-air collision (MAC), controlled flight into terrain (CFIT) and loss of control in-flight (LOC-I).

1.6 Consequently, States must both (a) deploy robust monitoring frameworks capable of detecting, analyzing and mitigating GNSS interference in real time, and (b) maintain a resilient terrestrial navigation infrastructure that allows safe reversion when GNSS is degraded or unavailable. This paper provides an overview of monitoring and reversion solutions serving Jeddah FIR and discusses how they combine into a single layered, multi-source navigation architecture.

2. THE NEED FOR A LAYERED, MULTI-SOURCE APPROACH

2.1 A two-part response: detect and revert

2.1.1 As recommended by ICAO, a resilient navigation strategy requires two complementary capabilities. The first is the ability to **detect and characterize** GNSS RFI or unavailability in real time, so that controllers and aircraft operators and crews gain situational awareness of where, when, and to what extent navigation is being affected or degraded. The second is the ability to **revert** to an independent, ground-based navigation means that maintains safe and continuous PNT during the disruption.

2.1.2 Detection without an alternative NAV capability leaves aircraft operations exposed once interference occurs; an alternative NAV capability without monitoring leaves ATCOs and flight crews unaware of when and where alternative NAV capability is required. **The two capabilities are therefore presented together: the GNSS Performance Monitoring System (GPMS) provides the detection layer, and an optimized DME-to-DME network provides the reversion layer (Alternative Capability).**

2.2 Alignment with the ICAO RON concept and the GNSS RFI Roadmap

2.2.1 ICAO is developing the Resilient Navigation Operational Network (RON) concept, which evolves the Navigation Minimum Operational Network (NAV MON) to better support States in transitioning from minimum navigational service levels to more resilient services that ensure operational safety and continuity during disruptions such as those caused by GNSS RFI.

2.2.2 The two layers presented in this paper map directly onto these RON objectives: the GPMS responds to the medium-term Onboard/Operational Monitoring Capability objective by delivering real-time

information on the status of GNSS and enhanced situational awareness, while the DME-to-DME optimization directly implements the terrestrial reversion infrastructure that RON is designed to optimize.

3. LAYER 1 — GNSS PERFORMANCE MONITORING SYSTEM (GPMS)

3.1 Need for advanced GNSS monitoring across the Jeddah FIR

3.1.1 Conventional monitoring solutions rely heavily on isolated data sources and cannot provide comprehensive situational awareness across an area of the size of the Jeddah FIR.

3.1.2 ATCOs and flight crews are provided with real-time information on the location, duration and extent of GNSS disruptions to ensure safe operations. Wide-area coverage is essential: localized monitoring cannot characterize interference that may affect large portions of the FIR simultaneously.

3.1.3 The historical data of GNSS RFI collected by ANSP will allow the ATS provider to transform from reactive monitoring (Tactical reaction) into a predictive and strategic thinking when establishing an airspace modernization, analysis study, or NAV MON study.

3.2 Challenges in implementing an effective GPMS

3.2.1 GNSS interference detection remains technically complex due to the inherently low power of satellite signals, their susceptibility to disruption, and the wide-area impact that interference sources can generate. Identifying the origin of such interference is often difficult, further complicating mitigation efforts.

3.2.2 The monitoring of GNSS requires the harmonization of data from multiple heterogeneous sources, managing differences in data formats, update rates and accuracy levels, while ensuring processing capabilities sufficient for real-time or near-real-time analysis and visualization.

3.2.3 Solutions that rely on ADS-B data alone are inherently reactive, as they provide information only after an aircraft has already been impacted. Conversely, wide-area monitoring can be challenging in States with large geographic areas. **A hybrid approach is therefore necessary to balance proactive and reactive detection.**

3.3 The hybrid monitoring approach

3.3.1 In response to these challenges, a multi-layered GNSS Performance monitoring system is recommended that integrate ground-based, airborne and independent surveillance data to provide a comprehensive and reliable assessment of GNSS performance across the Jeddah FIR.

3.3.2 **Ground-based GNSS sensors**, capable of determining the general location and type of RFI and distributed at key locations within the State, create a base layer of terrestrial monitoring. These sensors provide proactive detection of interference independent of aircraft presence.

3.3.3 **ADS-B as an airborne data source:** ADS-B messages, derived from onboard GNSS receivers, include performance indicators such as the Navigation Accuracy Category for Position (NACp) and the Navigation Integrity Category (NIC). By analyzing these parameters, the system detects degradation in GNSS performance as experienced by aircraft in real operational conditions. Consistent degradation across multiple aircraft in the same airspace is used to infer the presence and extent of GNSS interference.

3.3.4 ADS-B data is correlated with radar-based surveillance to identify discrepancies between GNSS-derived positions and independent radar tracks. This provides an additional validation layer and enables differentiation between GNSS-related anomalies and other system or sensor issues.

3.3.5 The fusion of these heterogeneous sources enables comprehensive, wide-area situational awareness. It allows GNSS anomalies to be detected and characterized with increased accuracy, supports the identification of affected areas in real time, and provides operational and technical stakeholders with actionable information.

3.4 Operational benefits

3.4.1 Real-time situational awareness of GNSS performance across the Jeddah FIR allows controllers to maintain continuous awareness of navigation system integrity and respond promptly to emerging interference events.

3.4.2 Early detection of GNSS degradation enables timely operational decision-making and the application of contingency procedures — including reversion to the DME-to-DME network described in Section 4 — where necessary.

3.4.3 GNSS Performance Monitoring System enhances confidence in the information presented to operational and technical personnel, enabling maintenance teams to investigate anomalies more efficiently and supporting coordination between technical and operational stakeholders.

3.4.4 GNSS Performance Monitoring System presents information clearly and reduces reliance on fragmented data sources, enhancing the overall resilience of air navigation services.

4. LAYER 2 — DME-TO-DME OPTIMIZATION SUPPORTING RON

4.1 Role of DME in PBN and GNSS reversion

4.1.1 DME is used in the en-route, terminal and approach phases to measure the distance between aircraft and ground stations. In the PBN context, DME-to-DME triangulation supports RNAV/RNP by providing continuous and reliable distance information independent of GNSS. DME-to-DME therefore represents the most feasible solution to ensure navigation performance when GNSS is unavailable due to interference or jamming.

4.1.2 Traditional DME systems, often paired with the ILS, typically use directional antennas that focus signals in specific directions. While effective for certain applications, directional antennas create coverage gaps and limit DME effectiveness for PBN, particularly in complex airspace or high-terrain areas, owing to limited coverage redundancy in specific sectors.

4.2 Key elements of the DME-to-DME enhancement

4.2.1 The improvement of the DME-to-DME network relies on two key actions:

- **Replacing the directional DME antennas** traditionally co-located with the ILS with **omnidirectional antennas**, which expand the range and uniformity of DME signals and increase the number of usable DME pairs for triangulation; and

- **Expanding the number and installation of stations**, including within suitable navigation sites inside the airport, without conflicting with system characteristics or affecting the signal.

4.2.2 Transitioning from directional to omnidirectional antennas is based on the results of coverage simulations and operational requirements, aligned with future airspace management plans. Technically, the DME equipment associated with the ILS also requires increasing the amplifier size in existing systems to match the new configuration and cover the maximum possible area.

4.3 Benefits of the DME-to-DME concept

4.3.1 The optimized DME network significantly outperforms traditional ground stations such as VOR in terms of PBN coverage, delivering up to a 35% improvement in coverage at low altitudes and up to an 85% improvement at high altitudes. This is particularly beneficial in remote and underserved areas, as it enhances signal redundancy across multiple regions.

4.3.2 The proposed solution can reduce navigation infrastructure costs by approximately 50% through the strategic placement of new DME stations and the rationalized decommissioning of certain VOR stations, while remaining feasible for developed airspaces.

4.3.3 Omnidirectional DME antennas co-located with ILS are more straightforward to install, maintain and integrate within existing DME networks, and reduce maintenance and operational costs when decommissioning certain VOR stations.

4.3.4 Improved PBN coverage enables more efficient flight paths, reduced fuel consumption and lower emissions, supporting more effective route planning and airspace utilization through more direct routes and fewer deviations.

4.4 How DME-to-DME contributes to RON and continuous, safe PNT

4.4.1 Under the RON concept, conventional terrestrial navigation aids serve three reversion functions: redundant aids supporting PBN navigation specifications and enabling cross-check with GNSS; as contingency support facilitating pilot positional awareness; and as established infrastructure for conventional Instrument Flight Procedures (IFP). An optimized DME-to-DME network supports the three reversion functions.

4.4.2 By providing a self-contained, ground-based positioning means, DME-to-DME ensures that PNT remains continuous and safe even when GNSS RFI occurs or is unavailable. It directly satisfies Assembly Resolution A42-8, Appendix C, which encourages States to ensure that sufficient resilient terrestrial CNS capabilities remain available, and it responds to AN-Conf/14 Recommendation 2.2/2 calling on States to maintain a sufficient network of conventional navigation aids.

4.4.3 Crucially, DME-to-DME removes reliance on a single GNSS as the sole source of position. Combined with the detection capability of the GPMS, it delivers the **robust, layered, multi-source** PNT architecture envisaged by ICAO: GNSS as the primary means, monitored continuously by the GPMS, with an optimized DME-to-DME network providing seamless reversion the moment GNSS performance degrades.

5. INTEGRATED ARCHITECTURE AND FUTURE CONSIDERATIONS

5.1 The combined architecture operates as a closed loop. The GPMS deployed by SANS continuously monitors GNSS integrity across the Jeddah FIR using ground sensors, ADS-B and independent surveillance. On detecting RFI or unavailability, it provides controllers with the location and extent of the affected area, prompting the application of contingency procedures and reversion to the DME-to-DME network, which maintains PBN/RNP operations until GNSS service is restored.

5.2 This integrated approach is consistent with the multi-layered strategy adopted at A42, which combines technical (C-PNT, signal authentication, RON/DFMC), operational (real-time reporting, monitoring), regulatory and strategic measures, and with the MID Region work under MIDANPIRG Decision 22/20 establishing the MID NAV-MON Action Group and the regional transition towards NAV RON.

5.3 There is a parallel need to promote standardized ICAO guidance and best practices for multi-source GNSS monitoring and for DME-to-DME optimization, facilitating harmonization across States and contributing to the regional objective of strengthening CNS system resilience. The possibility of extending the DME-to-DME coverage study to neighboring MID States should also be considered.

6. ACTION BY THE MEETING

6.1 The meeting is invited to:

- a) note the information in this paper;
- b) recognize the benefit GNSS Performance Monitoring System (GPMS) for real-time, wide-area detection and characterization of GNSS RFI or unavailability;
- c) recognize that an optimized DME-to-DME network, including the transition to omnidirectional antennas, provides the resilient terrestrial reversion capability required to ensure continuous, safe PNT, in line with the ICAO RON concept;
- d) encourage States to adopt layered, multi-source approaches that combine GNSS monitoring with resilient conventional navigation aids, and to conduct comprehensive DME-to-DME coverage analyses, including possible extension to neighboring MID States;
- e) support the development of ICAO guidance material for GNSS performance monitoring systems and for DME-to-DME optimization supporting RON; and
- f) promote Regional collaboration and data sharing for GNSS interference detection and mitigation, including coordination with the MID NAV-MON Action Group and the FM Working Group.