INTERNATIONAL CIVIL AVIATION ORGANIZATION

Performance Based Navigation Sub-Group

Third Meeting (PBN SG/3)
(Cairo, Egypt, 11 – 13 February 2018)

Agenda Item 3: Global and Regional Development related to PBN

INTRODUCTION TO RAIM PREDICTION SYSTEM

(Presented by IRAN)

SUMMARY

This Information Paper introduces RAIM (Receiver Autonomous Integrity Monitoring) prediction System.

Action by the meeting is at paragraph 3.

1. INTRODUCTION

1.1 Implementations of PBN and GNSS facilitate more efficient use of airspace and more flexibility for operational procedure. They cooperatively result in enhanced safety, access, capacity, predictability, operational efficiency, fuel economy, and environmental sustainability.

1.2 GNSS is considered the main navigation infrastructure supporting PBN operations. Navigation system performance requirements raise the need of deployments augmentation systems. Despite of variant augmentation systems ABAS (Aircraft Based Augmentation System) becomes one of the predominant augmentation system which deployed mostly in different phases of flight due to its numerous advantages. Aircraft-Based Augmentation System (ABAS) focuses on integrity only, and not on improving solution accuracy (i.e. no corrections are provided). Integrity failures can be a consequence of anomalies coming from the space, user and control segment or system allocated SIS aberrations. The most common anomaly source reported during GPS operations was clock anomalies in the space segment. Another example that has been observed is carrier leakage in the spectrum. Furthermore, since ground control segments of legacy GNSS did not have full time satellite visibility, an anomaly in one of the satellites could take up to a few hours to be identified and disseminated by the control segment. Under the GPS Standard Positioning Service (SPS) specifications, the probability of failure is approximately 10^{-4} per hour, whereas a number of operations require integrity risk to be bounded by 10^{-7} per hour.

1.3 According to ICAO Annex 10, two types of techniques are envisaged for ABAS:

- **Receiver Autonomous Integrity Monitoring (RAIM)**, which is most prevalent. In this technique only GNSS information is used.

- **Airborne Autonomous Integrity Monitoring (AAIM)**, where GNSS information is complemented with on-board sensors and other components.

2. DISCUSSION

Receiver Autonomous Integrity Monitoring (RAIM)

2.1 Receiver Autonomous Integrity Monitoring (RAIM) can be defined as a user algorithm that determines the integrity of the GNSS solution. The RAIM algorithm compares the smoothed pseudo range measurements among themselves to ensure that they are all consistent. Basically, RAIM algorithms make use of measurements redundancy to check the relative consistency among them (by means of the residuals) and in case of detection, the most likely "failed" satellite is determined. Many RAIM algorithms follow these steps:

Preliminary step: Compute the navigation solution,
Step 1: Fault detection Mechanism,
Step 2: Isolation of "faulty" satellites,
Step 3: Protection levels computation.

2.2 Taking into account that the user needs to solve four unknowns (3D position and clock) from the satellites, it follows that:

- 4 visible satellites are not enough to provide integrity;

- Fault Detection (FD): 5 visible satellites: if an anomaly is detected, the measurement from that specific satellite is discarded and therefore only 4 satellites are left. With only four satellites, the receiver does not have redundancy to compute the solution with different measurements and confirm that the solution is indeed correct. Therefore, the receiver is able to issue a warning but not to provide integrity; and

- Fault Detection and Exclusion (FDE): 6 or more satellites: the receiver is able to detect and perform the exclusion.

2.3 The more satellites in view, the more combinations of subsets of 4 satellites are available to detect potentially faulty satellites and the better the geometric observability. So unpredicted outages of GNSS services can cause undesired interruptions on aircraft operations. Safety impacts may become more severe during approach phase of flights especially if pilots are not aware of such outages. GPS (Global Positioning System) prediction service was a necessary part of GNSS approvals to allow for the fluctuations in service availability. Furthermore, GNSS is presently not only used for navigation, but is also becoming a critical component of surveillance system, such as ADS-B in addition to many aviation applications that depend on accurate timing such as SSR Radar.

2.4 ICAO Annex 10 and ICAO PBN manual require States and ANSPs to provide timely warnings of GNSS RAIM outages. A pre-flight GNSS RAIM prediction analysis is required by some civil aviation authorities (CAAs) for flights intending to use RNAV/RNP routes as well as departure and arrival procedures while using GPS as the sole navigation source.

2.5 RAIM prediction results are needed daily by pilots, flight dispatchers, air traffic controllers and airspace planners. The use of appropriate RAIM prediction services is considered to be a necessary part of GNSS approvals. Pilots and air traffic controllers need such information to ensure proper flight planning during possible service unavailability.

2.6 RAIM prediction is required for En-route, terminal area, and approach operations. RAIM prediction algorithms for different types of GNSS receivers and avionic configuration are also different.

Current PBN Manual RAIM Prediction Requirements

2.7 The PBN Manual contains numerous requirements for various forms of GNSS prediction plus requirements for ANSP providers to monitor the status of GNSS and issue timely warnings of outages (Paragraph 4.3.1.2). If predictions indicate that the maximum FDE outage time for the intended RNP 10 operation will be exceeded, then the operation must be rescheduled when FDE is available, or RNP 10 must be predicated on an alternate means of navigation (Paragraph 1.3.4.2.1.4). En-route RAIM levels are required for RNAV 5 and can be verified either through NOTAMs (where available) or through prediction services. The operating authority may provide specific guidance on how to comply with this requirement (e.g. if sufficient satellites are available, a prediction may not be necessary). Operators should be familiar with the prediction information available for the intended route. RAIM availability prediction should take into account the latest GPS constellation NOTAMs and avionics model. The service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver RAIM prediction capability. (Paragraph 2.3.4.3.1).

2.8 The following factors influence both status monitoring and RAIM prediction and these can differ between aircraft:

a) Receiver RAIM algorithms of different receivers;

b) Satellites in view can be a different set;

c) Receiver mask angle can vary; and

d) Integration with other sensors/aids (DME/DME, Baro, inertial) may or may not be available to the navigation system.

3. ACTION BY THE MEETING

3.1 The meeting is invited to note the information provided by this Information Paper.

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