Mitigation measures for GNSS failures

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ABSTRACT

Deterioration in the performance of GNSS services has become a global issue in recent years, and it is known to be caused by artificial radio frequency interference (RFI) and space weather effects.

The Network Performance Assessment Center (NPAC) of Japan Civil Aviation Bureau (JCAB), which was established in 2020, performs GNSS monitoring and performance assessment in Fukuoka FIR, and issues a NOTAM to notify GNSS service status.

This paper shows responses to events of artificial RFI that occurred off the coast of Hokkaido in 2021 as an example. In addition, it is known that solar activity will reach its peak in 2025, this paper shows NPAC's evaluation case of the space weather advisory service by ICAO, which was started in 2020.

INTRODUCTION

Global Navigation Satellite System (GNSS) is the core technology that has led to the development of Performance Based Navigation (PBN). It is also the basis for future improvements in navigation services, which is described in *ICAO Global Air Navigation Plan* (GANP: Doc 9750). GNSS is already the foundation of automatic dependent surveillance-broadcast (ADS-B) and automatic dependent surveillance-contract (ADS-C) which may lead to reduced separation standards.

GNSS signals from satellites are very weak at the receiver antenna, so are vulnerable to interference. *ICAO Global Navigation Satellite System Manual* (GNSS Manual: Doc9849) includes the mitigation strategy to both ensure the safety and regularity of air services and discourage those who would consider disrupting aircraft operations.

The need for an alternative position, navigation and timing (APNT) strategy has been identified as a mitigation strategy.

Japan Civil Aviation Bureau (JCAB) established the Network Performance Assessment Center (NPAC) in 2020 for the mission of centrally monitoring, analyzing and assessing service levels of CNS as the core of CNS performance management, which is an important key to realizing Performance Based Operation (PBO). NPAC collects GNSS signals and provides the following services to users:

a) GNSS performance prediction service for ABAS and SBAS.

b) GNSS performance monitoring service for aircrafts that use GNSS

c) GNSS performance analysis and evaluation service for users who use GNSS

These services are compliant with SARPs ANNEX 10 Vol. 1 attachment D Section 10.11.12 and *ICAO Global Navigation Satellite System (GNSS) Manual* (GNSS Manual: Doc9849) Chapter 7.

ICAO Global Navigation Satellite System (GNSS) Manual (GNSS Manual: Doc9849) includes the concept of GNSS monitoring, GNSS service status notification and anomaly reporting. And based on the manual, NPAC has established procedures for monitoring GNSS signals, disseminating the status, and responding to reception disturbances.

A case of GNSS signal outage in the oceanic airspace in Fukuoka FIR, as it might be caused by artificial RFI

Occurrence situation and actual response

NPAC detected 44 aircrafts of the deterioration of GNSS performance about 110NM southeastern offshore of Hokkaido on multiple routes to the United States. This phenomena had continued intermittently from September 22 to October 12 in 2021 . NPAC assessed the impact of this event, provided the relevant information to operators and investigated the cause.

a) Recognized a FOM deterioration*, which was included in ADS-C messages from aircraft, indicated value “4”, an alarm went off from ATC oceanic control system. Simultaneously, aircrafts reported that EICAS Advisory Message of ADS-B OUT had also occurred.

*The FOM value is an index related to position accuracy and 5 to 7 in normal condition.

b) Compared ADS-C with ADS-B information acquired by the GNSS performance monitoring service and understood the affected areas. As a result of that, we found that the outbreaks were concentrated in a specific area of NOPAC (R220) (Figures 1 and 2).

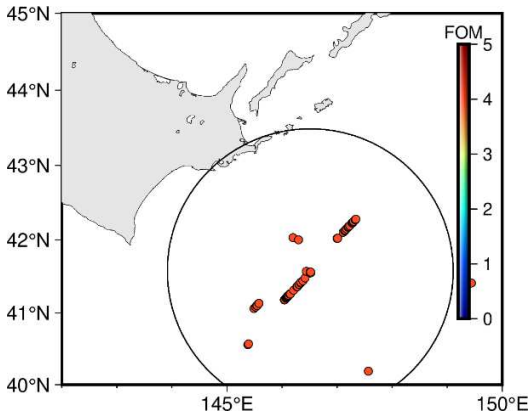

Figure1. ADS-C deterioration areas

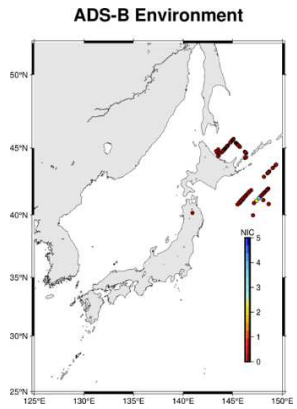

Figure 2. ADS-B deterioration areas

c) Confirmed that GPS health status and constellation from the GNSS performance monitor was in good condition.

d) Confirmed that there were no magnetic storms and radio bursts by space weather information.

e) Asked the flight inspector to special check the GPS signal.

NPAC shared with the flight inspector the location where the interference occurred and the time period of the interference and asked them to check.

With the spectrum analyzer data, only noise and no strong interference waves were observed. In addition, the number of receiving GPSs was 12, and the constellation was good, with HDOP: about 1 and VDOP: about 1.6. Based on the measurement results with the spectrum analyzer and the status of the GPS (Sufficient number and constellation), no interference that would cause the deterioration of navigation performance could be confirmed.

At the time of confirmation, it was thought that the noise source might have disappeared.

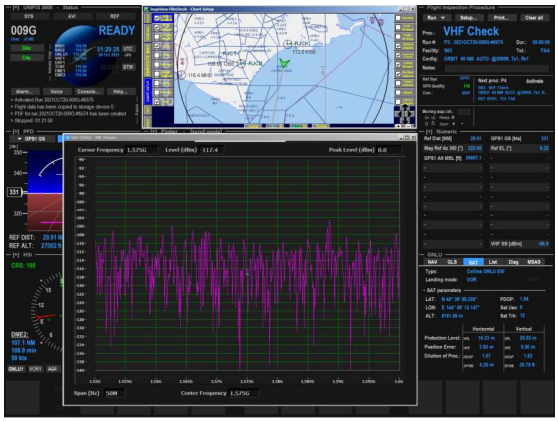

Figure3.Flight inspector confirmation results off the coast of Kushiro

f) Requested relevant authorities for cooperation. In consequence, the Regional Bureau of Telecommunications confirmed there was no noise found on land.

g) Although the above actions were taken, the root cause could not be identified, and NPAC issued the following NOTAM from October 14 to November 30. This event naturally disappeared and has not recurred.

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GPS POSITION ACCURACY MAY BE REDUCED WITHIN A 100NM RADIUS CENTERED ON 415457.90N 1465133.04E (WaypointName) ON THE FUKUOKA FIR.

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Note;

Issuing NOTAM of GPS performance deterioration is an effective way to indicate “position coordinate of center location or Waypoint” and “distance from center location” for pilots so that ND screen can display the affected areas. Therefore, it can not only provide visual recognition of that affected areas in which GNSS or ADS-B may not work normally to pilots in advance but also contribute to preventing unnecessary actions, miss operations and enhancing safety.

Building a system in response to this incident

Taking this event into consideration, NPAC will focus on grasping the situation and solving the problem immediately to provide helpful information as follows:

a) Create the RFI event reporting form to allow operators to promptly report necessary information when an event occurs.

We disseminated this form widely to Japanese airlines and requested them to report when an incident occurs.

b) Collect various data in real time and sharing the information with relevant authorities and organizations.
c) Determine the scope and extent of the impact and working to resolve the problem as soon as possible.
d) Build the collaborative system with frequency monitoring organizations (Ministry of Internal Affairs and Communications) and research institutes and proceed with necessary analysis.

e) Consider rapid issuance of procedures from the reporting of radio frequency interference (RFI) s to the issuance of NOTAM

f) Provide NOTAM in an operationally effective manner.

SPACE WEATHER ADVISORIES EVALUATION

A space weather section was added to ICAO ANNEX 3 (Meteorological services for international aviation), and the distribution of space weather advisories began on November 8, 2018. In Japan, the handling of space weather advisories is currently being sorted out, and we have notified ICAO of the differences. Considering that GNSS operations will progress in the future, NPAC is conducting an analysis of space weather advisories using ADS-B information.

We investigated the relationship between the navigation performance indicator information included in ADS-B on days when the disturbance situation was determined to be severe (SEV). Figure 4 shows the SEV advisory image on October 12, 2023. And Figure 5 focuses on the lower 3% of performance indicator value of ADS-B data for 24 hours on the day the SEV occurred. The white box indicate time when SEVs were forecast. In this investigation, no correlation had been observed.

There are few SEV advisories distributed to date as described in Figure 6, and we believe that further data collection is necessary for analysis. Considering that solar activity is on the rise, NPAC will continue to monitor and analyze it.

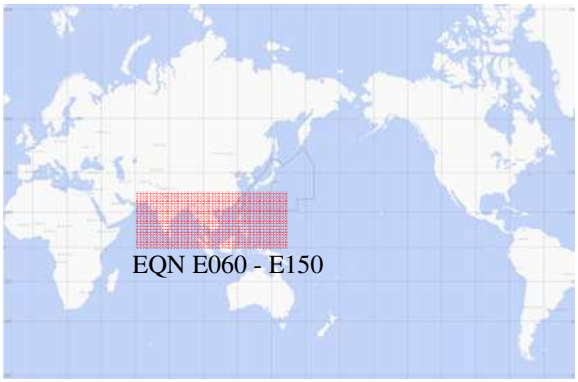

Figure4. SEV location on Oct.12th 2023(UTC)

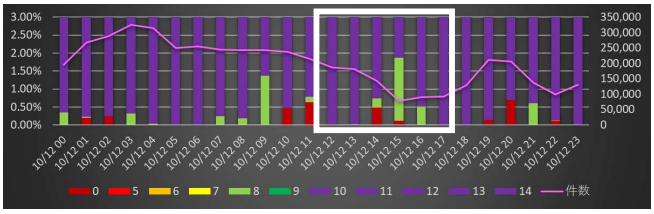

Figure 5 ADS-B performance indicator (PIC) value on Oct.12th 2023(UTC) when SEV occurred

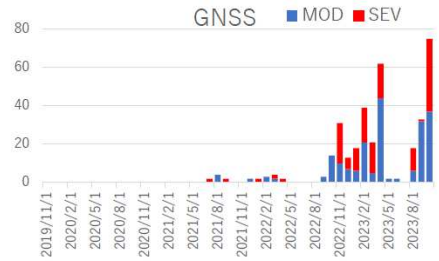

Figure6. Trends in the number of advisories

ICAO DISCUSSIONS ON THE APNT STRATEGY

GNSS enables PBN and provides navigation guidance for all phases of flight, from en-route through to precision approach. The need for the Alternative Position Navigation and Timing (APNT) strategy with the goal of maintaining services to the maximum extent possible in the event of a GNSS signal outage have been identified.

Furthermore, GNSS provides a precise time reference that is used to synchronize ground systems, onboard equipment, communication networks and operations. It is expected that having a system-wide time reference will become more critical in the future operational context (e.g. 4D trajectory-based operations). An alternative time source to GNSS is required to reduce the potential for interruption.

Japan actively contributes to ICAO discussions on the APNT strategy.

CONCLUSION

The Network Performance Assessment Center (NPAC) of JCAB, which was established in 2020, performs GNSS monitoring and performance assessment in Fukuoka FIR, and issues a NOTAM to notify GNSS service status to ensure the safety of air services.

It is important to have a mechanism of monitoring and reporting of GNSS RFI for relevant airspace users and air traffic controllers to be promptly and appropriately informed and to mitigate the impact on aircraft operations.

Japan actively contributes to ICAO discussions on the APNT strategy to maintain air navigation services to the maximum extent possible in the event of a GNSS signal outage.