CNS SG/7 Meeting

GNSS/GPS Interference

Reported in MID Region Jan-Dec. 2021

16-19 May 2022 Muscat, Oman

Global Aviation Data Management (GADM)

16 May 2022

Background – GNSS/GPS Vulnerability

- GNSS is a key technology of the Communications, Navigation, and Surveillance (CNS) infrastructure. GNSS can support navigation applications in all phases of flight as well as surveillance application like ADS-B. GNSS is also used in safety nets like the GPWS (Ground Proximity Warning Systems) and provides the time reference that is used to synchronize systems and operations in ATM.
- GNSS/GPS vulnerability, including intentional and unintentional signal interference, has been identified as a major safety issue as GNSS is embedded into numerous critical infrastructures. Especially the intentional interference presents significant threat to aircraft and passengers. Therefore, such interference needs to be monitored and its operational risk needs to be assessed.
- GADM IDX program enables identifying hot spots and trends of reported GNSS/GPS interference reports. Furthermore, GADM NOTAM repository enables tracking of any NOTAMs issued by States to inform potential GNSS/GPS Interferences to Airspace Users.
- To monitor the potential GNSS/GPS interference risk, IATA FDX program introduced new event of GPS outage from August 2021.

Background – GNSS/GPS Vulnerability Cont.

In April 2019, the RASG-MID released the guidance material to GNSS vulnerabilities to mitigate the safety and operational impact of GNSS service disruption. The guidance recommends **pilots to report GNSS interference** and **ANSP to issue appropriate advisories and NOTAMs**.

To support the joint-effort monitoring the GNSS/GPS Interference in the region, IATA GADM presented the first version of GNSS/GPS interference analysis in November 2020 and second version in July 2021. The GNSS/GPS Interference was published in 10th MID Annual Safety Report (2021) as one of the emerging safety risks in ICAO MID region.

In February 2022, the MIDANPIRG/19 & RASG/19-WP/16 was presented by IATA to provide the status of the GNSS and Radio Altimeter Interferences and proposed development of standard NOTAM text template to be used for GNSS Interference, to facilitate operators in filtering and searching through the NOTAMs.

In a continuous monitoring the regional safety risk of GNSS/GPS Interference, this analysis is presented to provide updated figure until 2021 December of GNSS/GPS Interference in MENA and adjacent countries.

IDX Rate Definition

The monthly IDX Event rate is defined as followings:

The number of events from IDX members, normalized by 1,000 takeoffs and landings .

$$\frac{Number\ of\ IDX\ Events\ occured\ in\ that\ month\ and\ proccessed}{Total\ number\ of\ takeoffs\ and\ landings\ of\ active\ IDX\ operators} \times 1000$$

For this analysis, the sum the number of takeoffs and landings from IDX participants, who actually submitted data for the month of reference is used. Those who did not submit any data in IDX for the month of reference are excluded.

In addition, for GNSS/GPS Interference reports, the number of takeoffs and landings are further filtered to departure and arrival pairs for each operator – summing all operators' (who submitted data to IDX for the given month) takeoffs and landings of the route (departure – arrival pair), where at least one GNSS/GPS interference report has been filed.

For example, the "GNSS/GPS Interference rate for January 2021, divided by 1,000 [takeoffs + landings]" is calculated as:

Count of the number of GNSS/GPS Interference events in IDX, reported in January 2021, Divided by the sum of [takeoffs + landings] count of the [departure-arrival pairs] from IDX participants who actually submitted data in January 2021, excluding participants who did not submit reports to IDX in 2021 January.

FDX Rate Definition

FDX Event Rate

Event Rate normalized as the number of event occurrences per 1000 flights flown in the given time period. This is calculated as:

$$\frac{number\ of\ events}{number\ of\ flights} \times 1000$$

In addition, for GNSS/GPS Interference reports, the number of flights are further filtered to departure and arrival pair by each operators – summing all FDX flights of the route (departure – arrival pair), where at least one GPS signal lost event has been detected.

FDX Eventful Rate

Eventful Rate normalized as the number of eventful flights per 1000 flights flown in the given time period. This is calculated as:

$$\frac{number\ of\ eventful\ flights}{number\ of\ flights} \times 1000$$

where an eventful flight is a flight with characteristics that have exceeded thresholds applicable to the aircraft type that have been designed to indicate abnormal or unusual activity.

Note: total number of flights processed in the FDX program by flight month is defined as number of flights for FDX rate calculation

In this analysis, the events of the GPS Signal Lost which have coordinates within Airport or FIRs in the MENA and neighboring States were used. The detailed geographic scope is shown in the page 8.

Analysis Scope – Data Coverage

This GNSS/GPS Interference analysis has completed using two dataset in GADM: **IDX (Incident Data Exchange)**, **FDX (Flight Data Exchange)** data and **NOTAM** information also held in IATA.

Incident Data Exchange (IDX)

Total **586** GNSS/GPS jamming or suspected interference reports from MENA and adjacent States have been reported by 15 operators in Incident Data Exchange (IDX).

- 2021 January ~ 2021 December (1 year)

Flight Data Exchange (FDX)

Total **46,936** GPS signal lost events from 38 operators from MENA and adjacent States have been extracted from Flight Data Exchange (FDX) dataset.

- 2021 August ~ 2021 December (5 months)

NOTAM

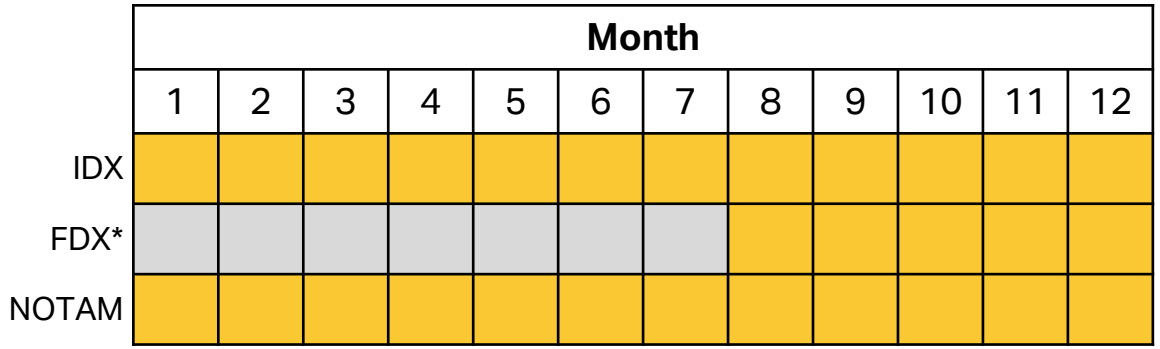
105 GNSS/GPS interference NOTAMs were extracted from NOTAM archive issued over MENA States.

- 2021 January ~ 2021 December (1 year)
- Source: FAA SWIFT Portal

2021 Monthly Data Coverage

Both IDX and NOTAM data have full coverage of the year 2021.

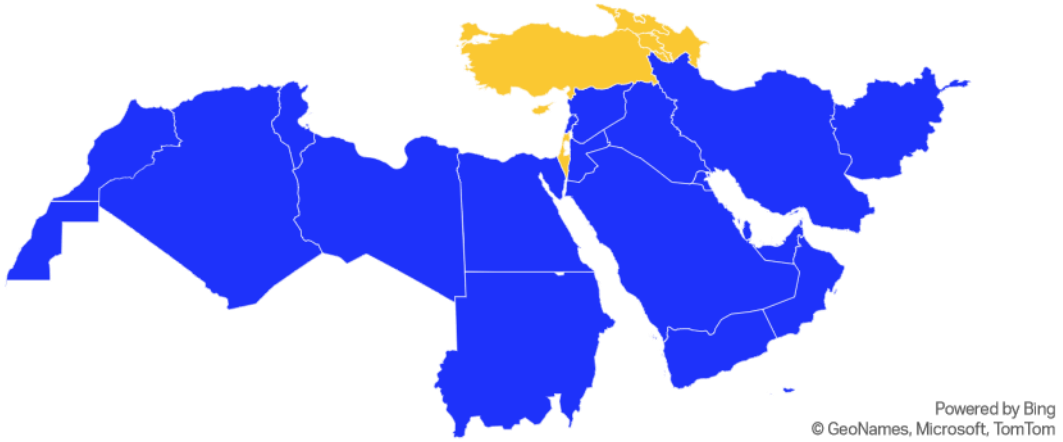
However, the FDX event "GPS signal lost" was introduced in August 2021, and therefore, only flight data submitted after August 2021 contain "GPS signal lost" event. For consistent rate monitoring, the FDX event "GPS signal lost" was extracted for flights conducted only from August 2021.



* Submitted Date and Event Date to be after August 2021. FDX member may submit historical data (e.g. flight data operated in June 2021 being submitted in September 2021). In this example, the GPS Signal Lost event may be tracked as the submitted date was after 2021 August. However, because such ratio or gap of "historical data submission" may vary depending on the operators, the filter was applied to extract data which was submitted after August 2021 with flights operated after August 2021, for consistent rate monitoring.

Analysis Scope – Geographic Scope

In previous analyses, it was that a considerate amount of the GNSS/GPS interferences were reported across the international borders. Therefore, the analysis is based on airports and airspaces in the expanded geographic coverage of MENA and adjacent States as below.



IATA MENA States:

- Afghanistan, Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, UAE, Yemen

Adjacent States included in this analysis:

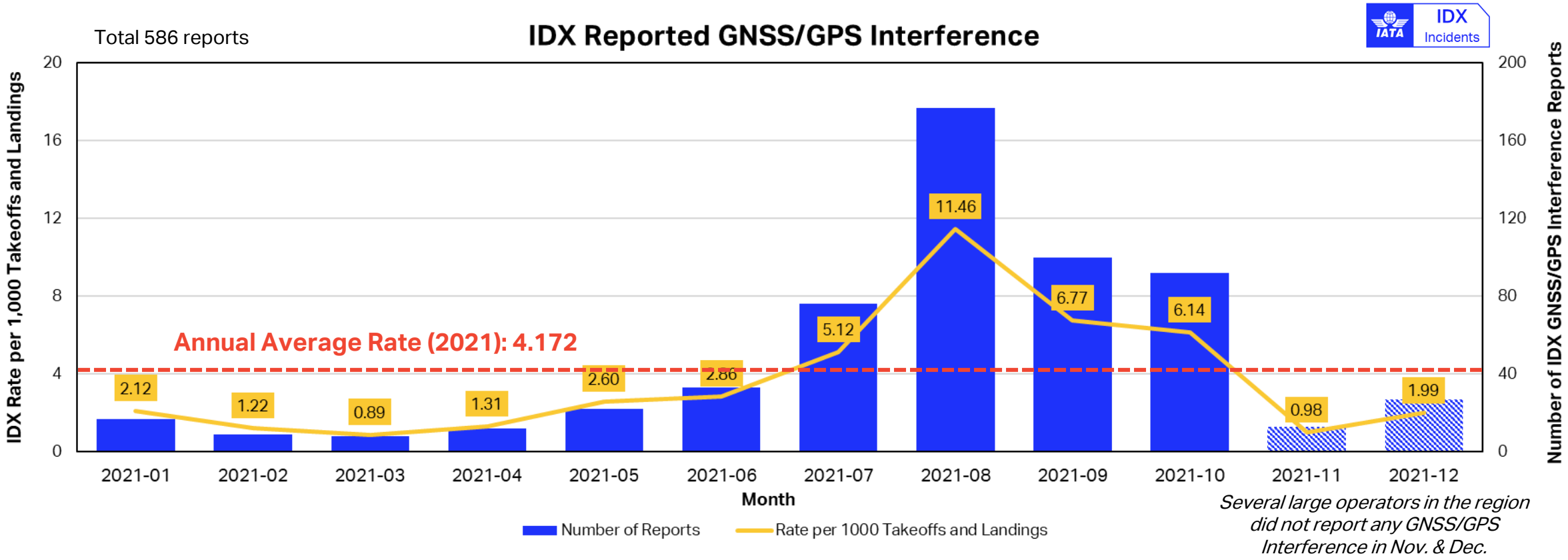
- Armenia, Azerbaijan, Cyprus, Georgia, Israel, Turkey

List of FIRs (Flight Information Regions)

In alphabetical order of FIR Code (as per 2021 December)

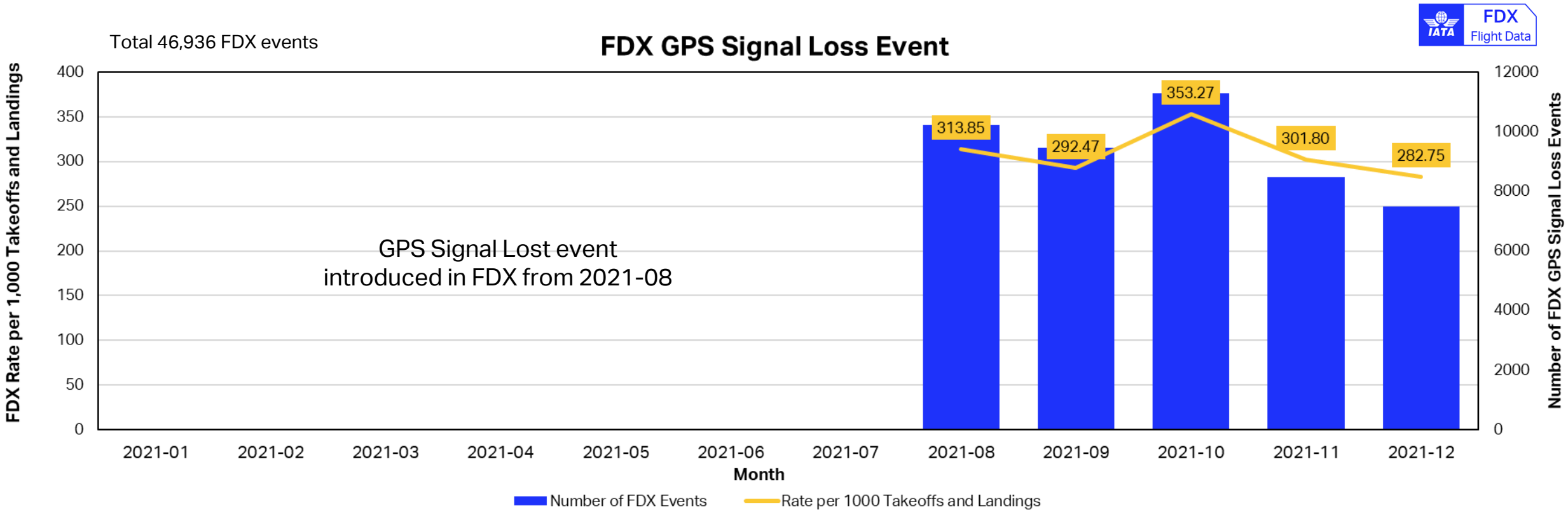
FIR Code	FIR Name	Country Code	Country
DAAA	Algiers	DZA	Algeria
DTTC	Tunis	TUN	Tunisia
GMMM	Casablanca	MAR	Morocco
HECC	Cairo	EGY	Egypt
HLLL	Tripoli	LBY	Libya
HSSS	Khartoum	SDN	Sudan
LCCC	Nicosia	CYP	Cyprus
LLLL	Tel-Aviv	ISR	Israel
LTAA	Ankara	TUR	Turkey
LTBB	Istanbul	TUR	Turkey
OAKX	Kabul	AFG	Afghanistan
OBBB	Bahrain	BHR	Bahrain
OEJD	Jeddah	SAU	Saudi Arabia
OIIX	Tehran	IRN	Iran
OJAC	Amman	JOR	Jordan
OKAC	Kuwait	KWT	Kuwait
OLBB	Beirut	LBN	Lebanon
OMAE	Emirates	ARE	UAE
OOMM	Muscat	OMN	Oman
ORBB	Baghdad	IRQ	Iraq
OSTT	Damascus	SYR	Syria
OYSC	Sanaa	YEM	Yemen
UBBA	Baku	AZE	Azerbaijan
UDDD	Yerevan	ARM	Armenia
UGGG	Tbilisi	GEO	Georgia

GNSS/GPS Interference Trend



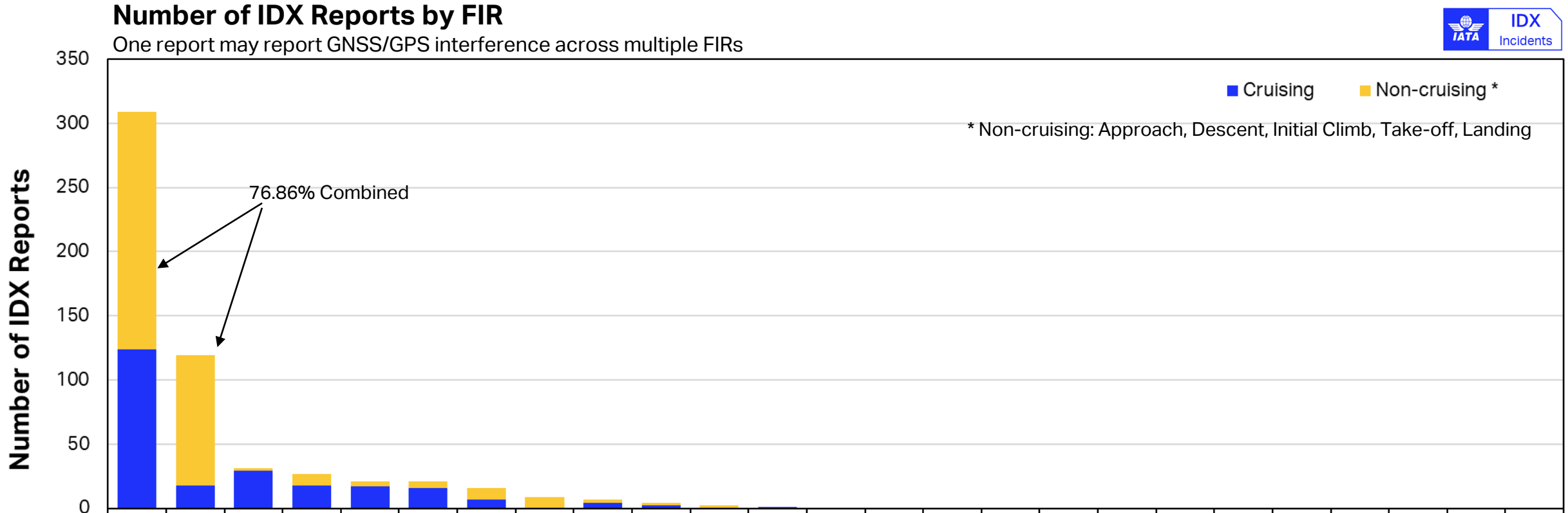
The number of GNSS/GPS interference reports has increased significantly during June ~ August 2021, peaked in August with the rate of 11.46 per 1,000 takeoffs and landings. Afterwards, the rate of GNSS/GPS Interference has been decreased to 6.77 and 6.14 in September and October, then dropped below than the annual average of 4.17 in November and December.

GNSS/GPS Interference Trend



However, the FDX rate shows relevantly consistent event rate from August to December 2021. Considering (1) the number of FDX events (46,936 events) was larger than IDX reports (586 reports), (2) the number of FDX operators with at least one event (38 operators) was higher than the ones from IDX (15 operators) and (3) the difference of data collection methods, where IDX event relies on voluntary reporting from crew, while FDX event is captured automatically from the flight data recorder, it is likely that the GNSS/GPS interference in the region may not have decreased during August ~ December 2021, as shown in FDX rate.

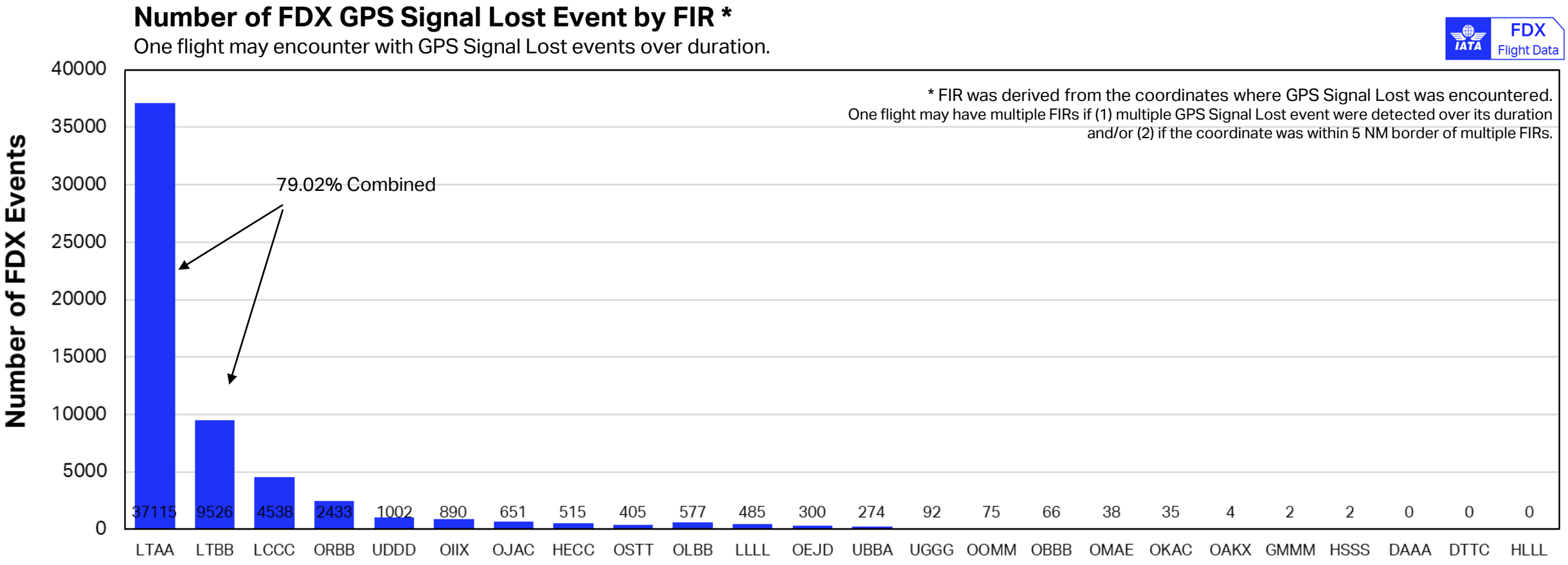
Distribution of GNSS/GPS Interference by FIR



	LTAA	LTBB	OIIX	LCCC	HECC	ORBB	LLLL	OLBB	OJAC	UBBA	OBBB	OMAE	DAAA	DTTC	GMMM	HLLL	HSSS	OAKX	OEJD	OKAC	OOMM	OYSC	UDDD	UGGG	OSTT
Non-cruising *	185	101	2	9	4	5	9	9	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruising	124	18	29	18	17	16	7	0	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

In IDX, the FIR with highest number of reported GNSS/GPS Interferences was **LTAA (Ankara FIR)**, followed by **LTBB (Istanbul FIR)**, **OIIX (Tehran FIR)**, **LCCC (Nicosia FIR)**, **HECC (Cairo FIR)**, **ORBB (Baghdad FIR), LLLL (Tel-Aviv FIR), OLBB (Beirut FIR)** and **OJAC (Amman FIR)**. The rest of the FIRs had less than 10 reported GNSS/GPS Interference. 76.86% of all GNSS/GPS Interference reports was collected in Turkish FIRs. Notably, the number of reports in **LTBB (Istanbul FIR)** has significantly increased compared to previous analysis.

Distribution of GPS Signal Lost by FIR

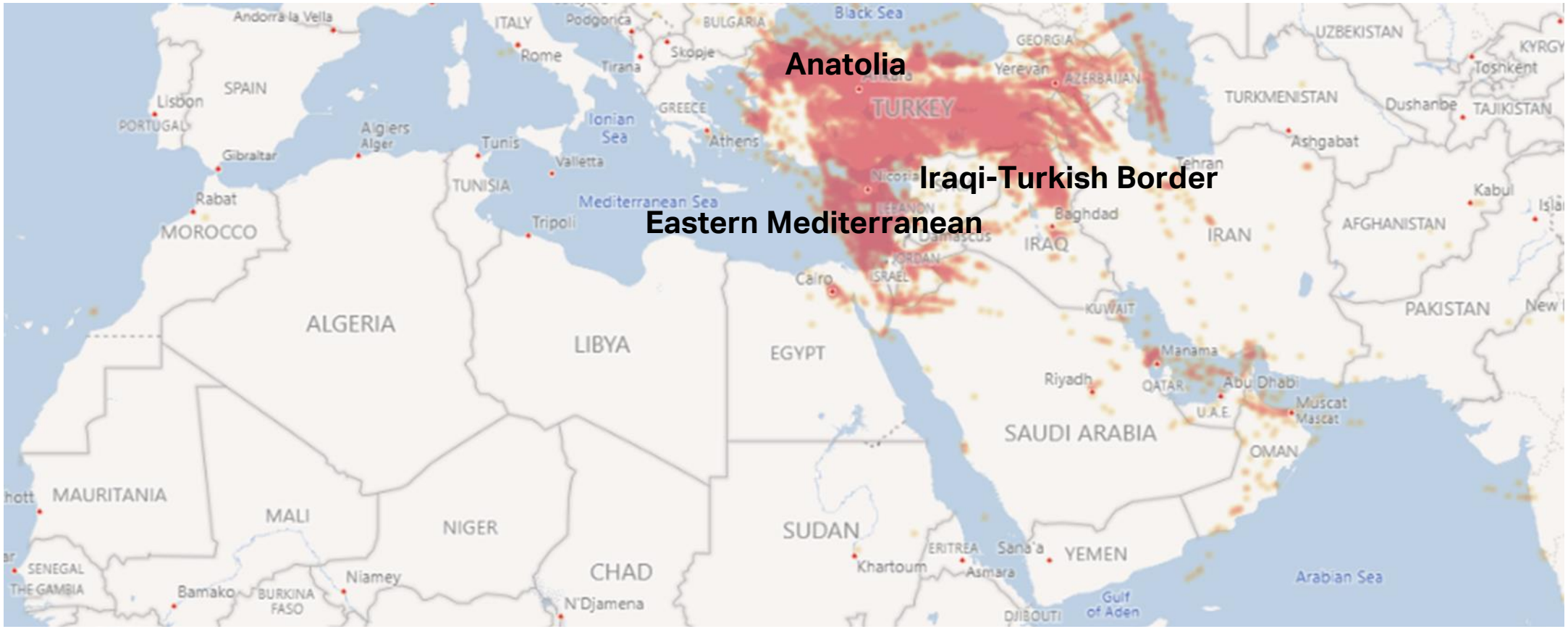


Similarly, the FIR with highest number of FDX GPS Signal Lost events was **LTAA (Ankara FIR)**, followed by **LTBB (Istanbul FIR)**, **LCCC (Nicosia FIR)**, **ORBB (Baghdad FIR), UDDD (Yerevan FIR), OIIX (Tehran FIR)**, **OJAC (Amman FIR), HECC (Cairo FIR)**, **OSTT (Damascus FIR), OLBB (Beirut FIR), LLLL (Tel-Aviv FIR), OEJD (Jeddah FIR) and UBBA (Azerbaijan).** The distribution of GPS Signal Lost event from FDX follows similar pattern of that from IDX. The rest of the FIRs had less than 100 GPS Signal Lost Events.

GPS Signal Lost Hot-Spots

Reported coordinates of FDX GPS Signal Lost Event

One flight may encounter with GPS Signal Lost events over duration.



Majority of GPS Signal Lost was detected within or in vicinity of Turkish airspace (Ankara FIR and Istanbul FIR), and in Eastern Mediterranean area. Compared to previous analysis, the identified hot-spots have been expanded into entire Anatolian peninsula, including Istanbul FIR (LTBB).

GPS Signal Lost Hot-Spots

IDX Incidents | FDX Flight Data

List of FIRs identified as Hot-Spots

The aggregated numbers of events from following FIRs counts 98.87% of all GNSS/GPS Interference in IDX and 98.34% of GPS Signal Lost in FDX.

FIR Code	FIR Name	Country	IDX Distribution p.12	FDX Distribution p.13
LTAA	Ankara	Turkey	55.18%	70.98%
LTBB	Istanbul	Turkey	21.68%	11.93%
LCCC	Nicosia	Cyprus	4.69%	4.92%
ORBB	Baghdad	Iraq	3.40%	2.61%
OIIX	Tehran	Iran	5.02%	1.62%
HECC	Cairo	Egypt	3.40%	1.05%
LLLL	Tel-Aviv	Israel	2.75%	0.65%
OJAC	Amman	Jordan	1.13%	1.13%
OLBB	Beirut	Lebanon	1.62%	0.71%
UDDD	Yerevan	Armenia	0.00%	1.89%
OSTT	Damascus	Syria	-.--% *	0.83%
Total			98.87%	98.33%

* No IDX member has operated over OSTT,

Ratio of global flights over identified Hot-Spots.

5.2% of global flights in the year 2021 have operated within or crossed the listed FIRs.
This not only includes more than 45% of departures / arrivals in MENA, but also affecting flights operating between other regions, such as EUR-ASPAC, EUR-NASIA or CIS-AFI, which are crossing these FIRs.

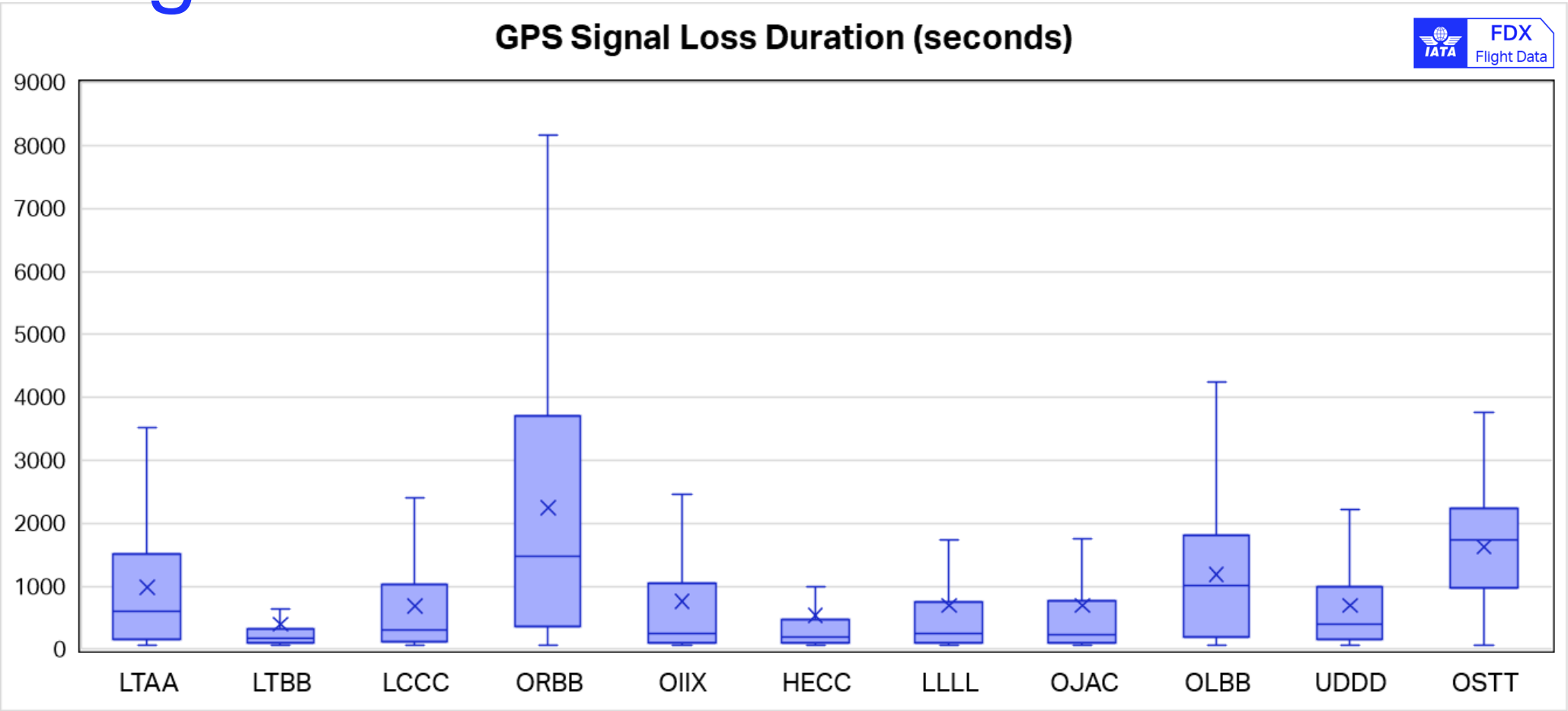
Arrival Region →

Departure Region →

	AFI	ASPAC	CIS	EUR	LATAM/ CAR	MENA	NAM	NASIA	Unknown	Total
AFI	0.0%	0.6%	**86.1%**	**44.4%**	0.0%	**15.9%**	0.0%	0.1%	0.3%	4.9%
ASPAC	0.4%	0.0%	**23.7%**	**40.3%**	0.0%	**20.2%**	0.9%	0.0%	0.1%	1.2%
CIS	**93.4%**	**27.8%**	2.3%	**51.4%**	0.0%	**96.9%**	0.8%	0.6%	4.8%	11.4%
EUR	**36.8%**	**44.9%**	**53.1%**	12.4%	2.6%	**71.0%**	5.6%	**16.7%**	8.4%	15.1%
LATAM/CAR	0.0%	0.2%	0.3%	2.7%	0.0%	10.4%	0.0%	0.0%	0.0%	0.1%
MENA	**14.8%**	**26.9%**	**96.8%**	**70.6%**	1.8%	**46.2%**	**90.6%**	**34.1%**	**22.1%**	46.9%
NAM	**30.1%**	1.3%	3.1%	5.4%	0.0%	**91.1%**	0.0%	0.0%	0.0%	0.2%
NASIA	0.0%	0.0%	1.2%	**14.4%**	0.0%	**26.2%**	0.0%	0.0%	0.0%	0.2%
Unknown	0.3%	0.1%	7.8%	2.9%	0.0%	**31.2%**	0.0%	0.1%	4.2%	3.6%
Total	4.4%	1.6%	11.8%	15.3%	0.1%	48.3%	0.2%	0.2%	3.3%	5.2%

Data Source: Flightradar24

GPS Signal Lost Duration



Sorting by average seconds of GPS Signal Lost duration in descending order, **ORBB (Baghdad FIR)** had the longest duration, in average of 2,251 seconds, followed by **OLBB (Beirut FIR)** with 1,184 seconds, **LTAA (Ankara FIR)** with 984 seconds, **OIIX (Tehran FIR)** with 760 seconds, **OJAC (Amman FIR)** with 699 seconds, **LLLL (Tel-Aviv FIR)** with 697 seconds, **UDDD (Yerevan FIR)** with 691 seconds, **LCCC (Nicosia FIR)** with 687 seconds, **HECC (Cairo FIR)** with 536 seconds and **LTBB (Istanbul FIR)** with 402 seconds.

GNSS/GPS Interference Narrative Example

"From just after entering *** FIR through *** and into *** up until landing at *** repeated loss of GPS signal suspect due to jamming. This manifested itself in loss of **GPS L and R, loss of ADS-B out, navigation accuracy degradation and numerous EICAS and Status messages** with and without associated check lists."

"Shortly after departure we lost GPS signals. During descend phase around FL230 we got **'TERRAIN TERRAIN PULL UP'** warning shortly captain applied corrective maneuver. But it was very obvious it was spurious (we were in very shallow descent in clear sky) we resumed normal operation."

"The date of flight there was a GPS signal interruption on our route and approach phase frequently. The ILS approach was performed and stabilization criteria are met for RWY ***. In the landing phase, aircraft was land between last third and second touchdown zone markings (the touchdown was closest to last second touchdown zone markings). When the aircraft was touchdown, the last touchdown zone marking clearly identifiable and in front of the aircraft. Therefore, any report was not filled out, due to landing was performed in touchdown zone markings." **(False Long Landing due to GNSS Signal Interruption)**

GNSS/GPS Interference NOTAM Issued

Active GNSS/GPS Interference NOTAM Coverage from 2021-01 to 2021-12

Yellow Cell: One or more than one NOTAMs warning about potential GNSS/GPS Interference were active during the month.
Red Cell: More than 3 GNSS/GPS Interferences were reported in IDX but no warning NOTAM was active during the month.

FIR		2021-01	2021-02	2021-03	2021-04	2021-05	2021-06	2021-07	2021-08	2021-09	2021-10	2021-11	2021-12	# of NOTAM Issued
Ankara FIR	LTAA	10	5	4	5	17	23	40	88	77	57	8	7	3
Istanbul FIR	LTBB	0	1	1	2	2	7	11	70	12	28	0	0	1
Nicosia FIR	LCCC	4	2	1	1	1	0	7	4	1	1	0	7	2
Baghdad FIR	ORBB	0	0	2	0	1	3	7	6	1	1	0	0	3
Teheran FIR	OIIX	0	0	0	0	0	1	1	0	0	9	10	10	25
Cairo FIR	HECC	1	1	0	3	0	0	3	0	1	2	0	10	1
Tel-Aviv FIR	LLLL	1	1	0	1	0	0	8	3	1	0	0	2	49
Amman FIR	OJAC	0	0	1	0	0	0	2	1	0	1	0	2	2
Beirut FIR	OLBB	0	0	0	0	2	0	2	1	3	2	0	0	2

In most of the FIRs with reported GNSS/GPS Interferences, there were active NOTAMs warning the operators about potential GNSS/GPS Interference risk. However, In Istanbul FIR on 2021 June, Baghdad FIR on 2021 July ~ August and Cairo FIR on 2021 December, there were no NOTAM warning operators about the GNSS/GPS Interference risk.

Some FIRs such as OIIX (Teheran FIR) and LLLL (Tel-Aviv FIR), had issued high number of NOTAMs with short durations (e.g. several days or hours), while other part of the area issued NOTAMs with longer duration.

- Data Source: Federal NOTAM Service (FNS), Distributed from SWIFT Portal: https://portal.swim.faa.gov/

Conclusion

The meeting is invited

- to endorse amendment of RSA-14 Advisory “Guidance Material Related to GNSS Vulnerabilities “ to include the updated information on GNSS interference.

Acronyms List

- **ADS-B**: Automatic Dependent Surveillance - Broadcast
- **ANSP**: Air Navigation Service Provider
- **ASR:** Air Safety Report
- **ATM**: Air Traffic Management
- **ECAM**: Electronic Centralized Aircraft Monitor
- **EGPWS/GPWS**: (Enhanced) Ground Proximity Warning System
- **EICAS**: Engine-Indicating and Crew Alerting System
- **FIR**: Flight Information Regions
- **FMS**: Flight Management System
- **GADM:** Global Aviation Data Management
- **GNSS**: Global Navigation Satellite System
- **GPS**: Global Positioning System
- **IDX**: Incident Data Exchange
- **MENA**: Middle East and North Africa
- **ND**: Navigation Display
- **NOTAM**: Notice-to-Airmen
- **PBN**: Performance Based Navigation
- **RAIM**: Receiver Autonomous Integrity Monitoring
- **RASG-MID**: Regional Aviation Safety Group – Middle East
- **RNP**: Required Navigation Performance
- **TAWS**: Terrain Awareness and Warning System

Reference Materials

- IATA, GNSS Interference Impacts to airline operations, 4 March 2021
- IATA, GNSS/GPS Interference Reported in MENA Region, 11 November 2020
- IATA, GNSS/GPS Interference Reported in MENA Region (Updated), 30 August 2021
- IATA, Harmful Interference to Global Navigation Satellite System (GNSS) and its impacts on flight and air traffic management operations, 29 April 2019
- ICAO MID Region Annual Safety Report 10th Edition, 2021
- ICAO MID ANPIRG/19 & RASG-MID/9-WP/16: Air Navigation Subjects of interest to RASG-MID including RVSM operations and Monitoring, 9 February 2022
- ICAO A40-WP/188: An Urgent Need to Address Harmful Interferences to GNSS, IFATCA, IFALPA and IATA, 5 August 2019
- ICAO MIDANPIRG CNS SG/9-WP/12: GNSS Issues, 18 March 2019
- RASG-MID Safety Advisory -14 (RSA-14): Guidance Material Related to GNSS Vulnerabilities, April 2019
- RASG-MID/6-WP/27: GNSS Vulnerability, 13 September 2017
- IFALPA, 19SAB07: GNSS Vulnerabilities, 18 July 2019
- Eurocontrol, Aviation Intelligence Unit Think Paper #9 -Does Radio Frequency Interference to Satellite Navigation pose an increasing threat to Network efficiency, cost-effectiveness and ultimately safety?, 1 March 2021
- Eurocontrol, voluntary ATM incident reporting (EVAIR) safety bulletin, 23 February 2022
- EASA, Safety Information Bulletin 2022-02, Global Navigation Satellite System Outage Leading to Navigation / Surveillance Degradation, 17 March 2022

Thank You