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SUSTAINABLE FUTURE.

Mr. Kyung Won Lee

GNSS RFI in Republic of Korea

– Challenges and associated Regulations

01 GNSS RFI - introduction

02 GNSS performance degradation

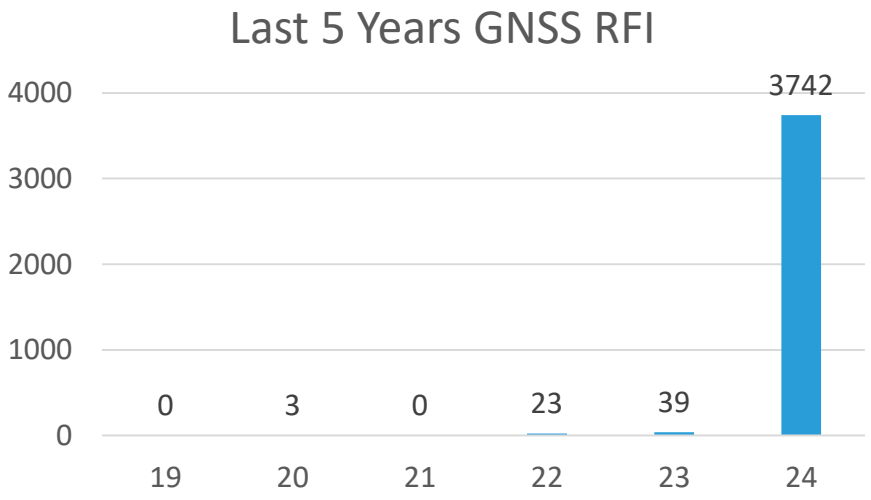
03 GNSS signal monitoring – ADS-B & KASS

04 Conclusions

GNSS RFI

Intentional GNSS RFI in RoK

- The frequency of GPS RFI is increasing in some regions, and related reports are on the rise.
- It affects aircraft as well as GNSS navigation equipment on sea and land.
- Airports located in the metropolitan area have issued related NOTAMs to warn against the use of GNSS.



GNSS RFI evolution
(from MOLIT)

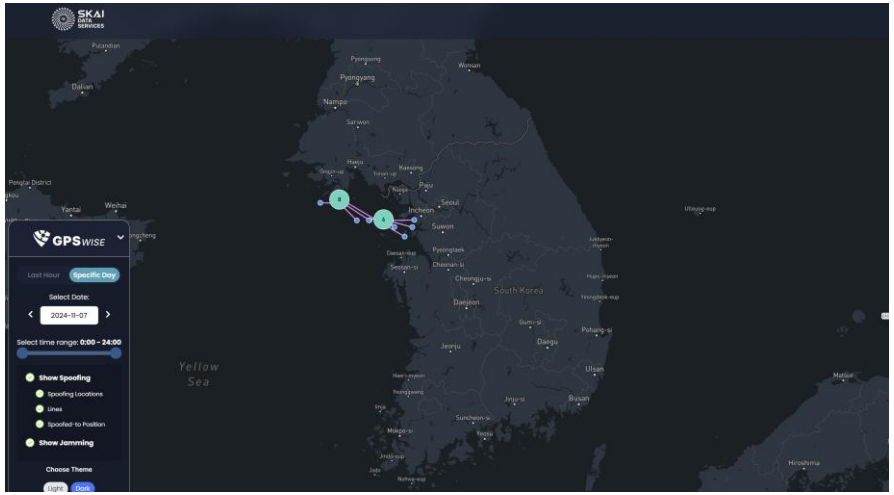
'19	'20	'21	'22	'23	'24
0	3	0	23	39	3,742

Report GPS Interference
(from MOLIT)

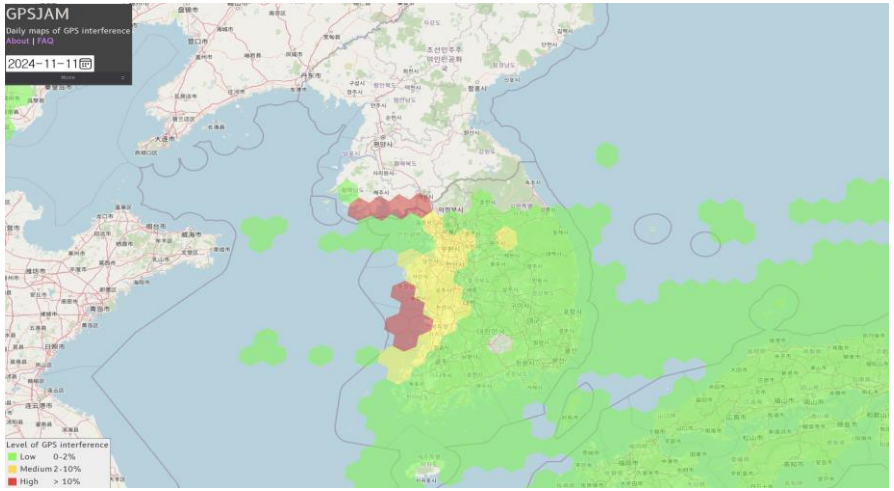
GNSS RFI

Impact of jamming and spoofing in Korea

- **GPS Jamming and GPS Spoofing Around the Korean Peninsula**
  - Jamming and spoofing occur frequently around the Military Demarcation Area on the Korean Peninsula.
  - As an example: 2024.11.1.~11.10. A total of 331 GPS anomaly reports received, including 279 aircraft and 52 ships



Live GPS Spoofing and Jamming Tracker Map
(from SKAI)



Daily maps of GPS interference
(from GPSJAM, 11-11-2024)

GNSS RFI

Domestic Regulations Concerning GNSS RFI

- ICAO Annex 10 Volume I : Radio Navigation Aids

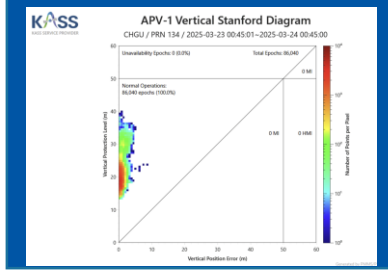
(domestic regulations)

- laws relating to the definition and management of radio waves
  - RADIO WAVES ACT, ENFORCEMENT DECREE OF THE RADIO WAVES ACT
- laws relating to aviation safety
  - AVIATION SAFETY ACT, ENFORCEMENT DECREE OF THE AVIATION SAFETY ACT
- laws relating to airport facilities
  - AIRPORT FACILITIES ACT, ENFORCEMENT DECREE OF THE AVIATION SAFETY ACT
- For KASS
  - Regulations for Operation and Management of KASS

02

GNSS Performance degradation

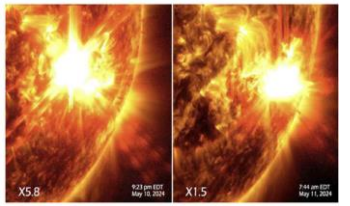
-



GNSS Performance degradation

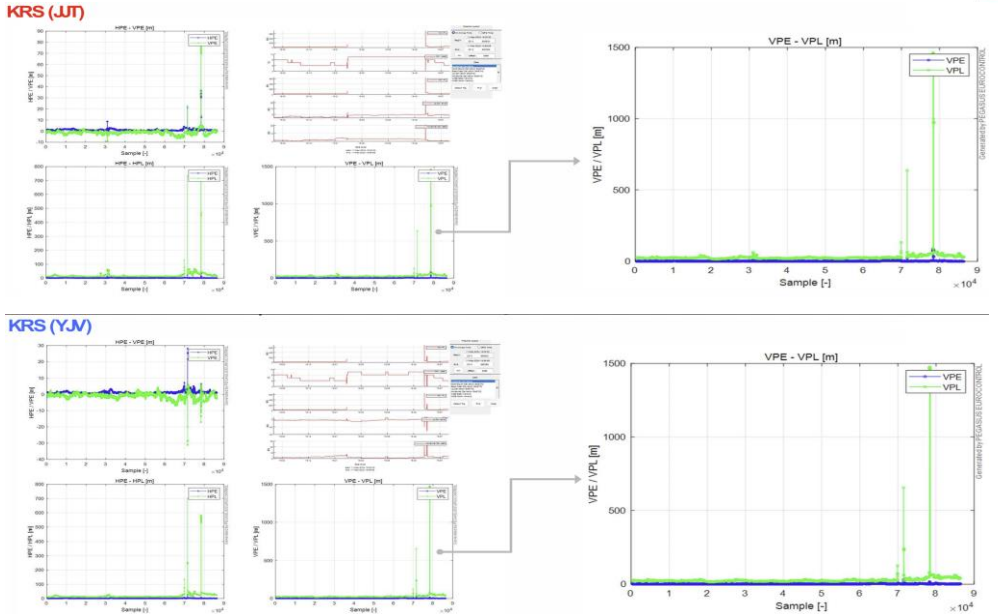
Natural GNSS radio frequency interference

- Solar activity affects the activity of the Earth's ionosphere, which in turn affects GNSS performance.
- The sun's solar activity is expected to peak between late 2024 and early 2026, marking the beginning of the 25th sola cycle's maximum.



[Pictures captured by NASA's Solar Activity Observatory on May 10th (left) and 11th (right), 2024]

Solar cycle progression
(from Space Weather Prediction Center)

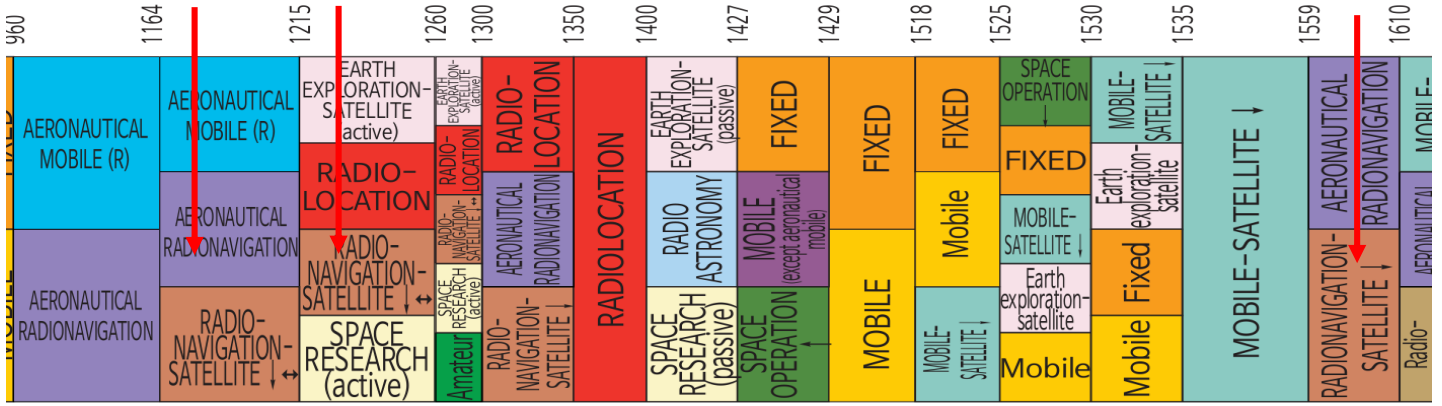


GNSS Performance of KASS
(on May 10th~11th)

GNSS Performance degradation

Frequency interference between different equipment

- **GPS L-Band center frequency(L1: 1575.42 MHz, L2: 1227.60MHz L5: 1176.45MHz) has a lot of interference signals by time and region.**
  - AERONUTICAL MOBLIE: (DME[960-1215MHz], TACAN[962-1213MHz])
  - RADIO-LOCATION: (ASSR: Air Route Surveillance Radar [1.25-1.26, 1.34-1.35, 1.35-2.79GHz)
  - Military Applications (Link-16[960-1,215MHz])
  - Unknown frequency
- Equipment with overlapping bands may affect GNSS reception.

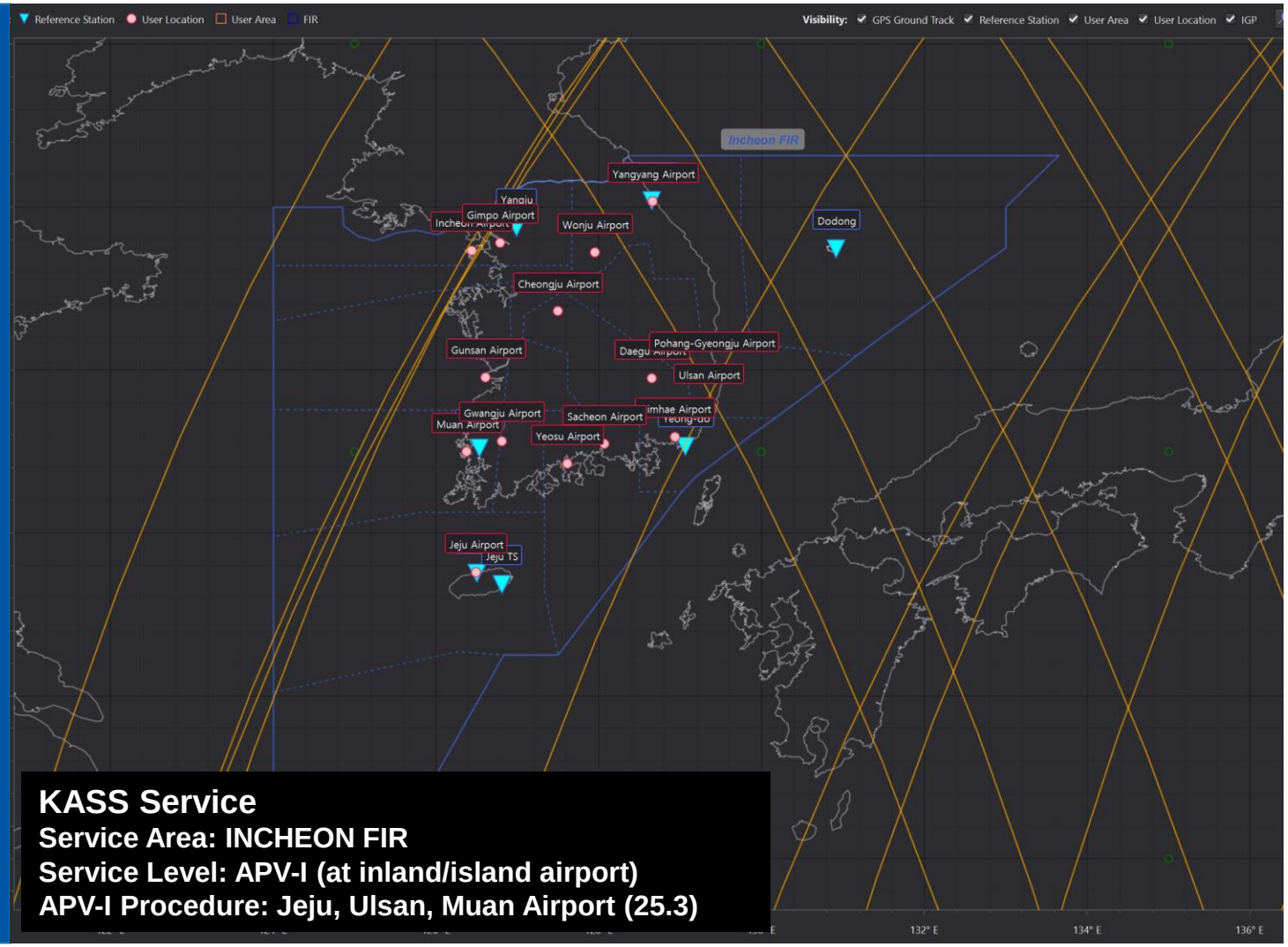


Frequency Spectrum Table Around GPS L Band

(from Korea Communications Agency & Ministry of Science and ICT (MSIT))

03

GNSS RFI monitoring



KASS Service
Service Area: INCHEON FIR
Service Level: APV-I (at inland/island airport)
APV-I Procedure: Jeju, Ulsan, Muan Airport (25.3)

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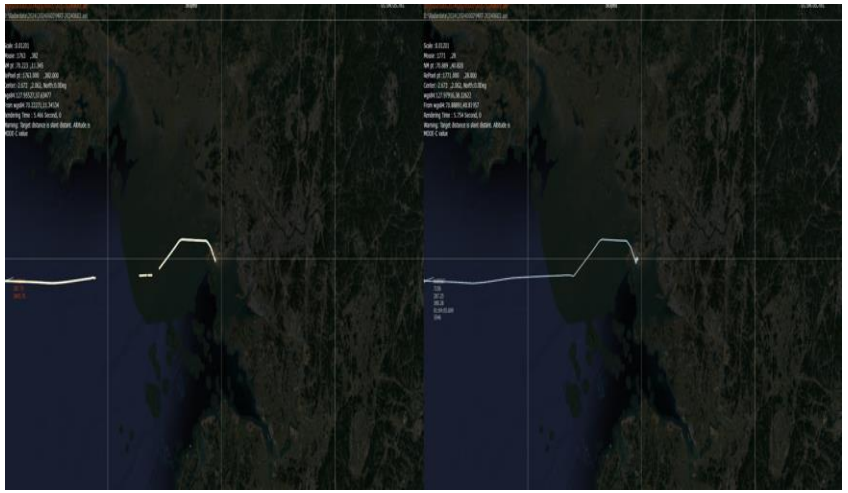
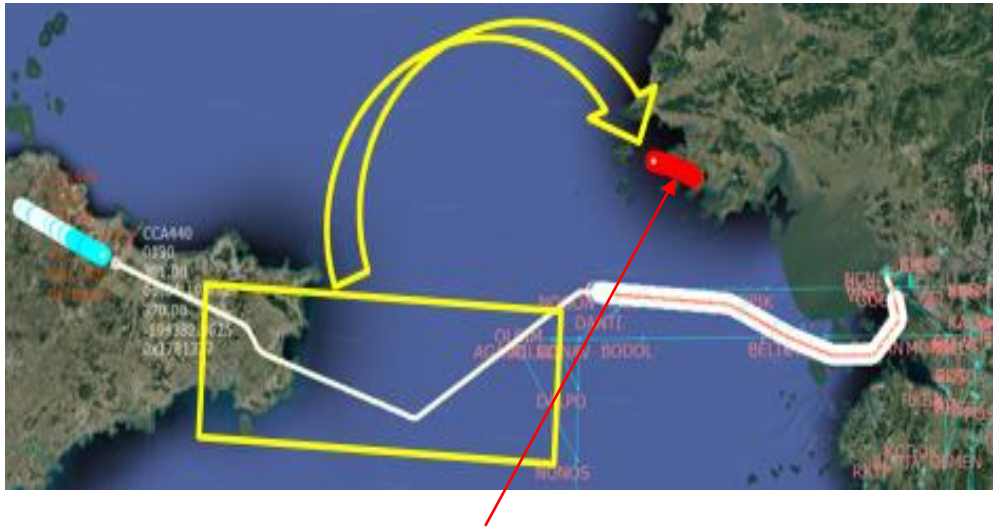
GNSS signal monitoring (from Seoul APP)

Signal analysis results for ARTS(ASR and ADS-B)

- **RFI analysis for ADS-B signal**
- **Irregular monitoring of radio interference in the ADS-B(estimating spoofing)**
  - **ADS-B NIC is 1 to 8**



GNSS Jamming
(Left ADS-B only / Right MRT)

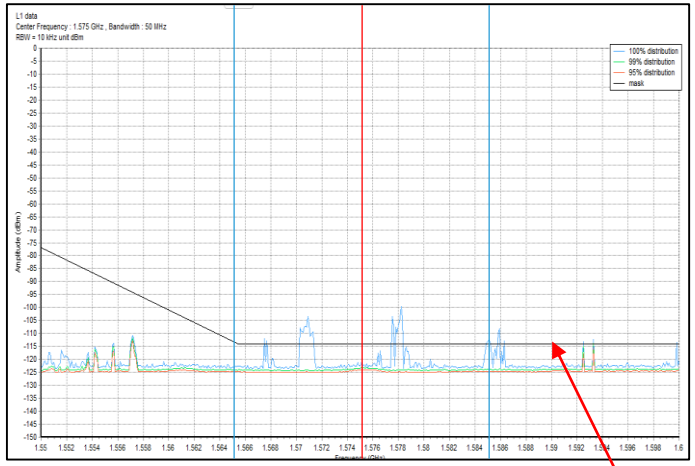


Estimating Spoofing
(White MRT / Red Spoofing)

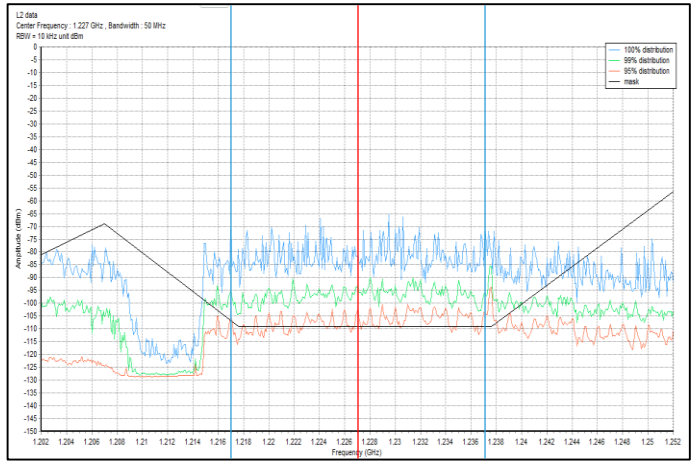
GNSS signal monitoring (from L-Band)

Signal analysis results for GPS L-band (Spectrum analysis) #1

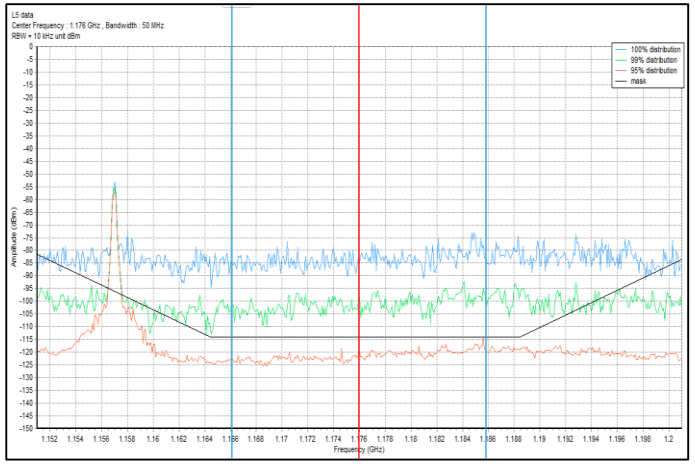
- **RFI analysis for GNSS bands during GNSS reference station site construction and regular analysis**
- **Irregular monitoring of radio interference in the GPS L-band**



GPS L1 (In/Near band)
(@Cheongju site)



GPS L2 (In/Near band)
(@Cheongju site)



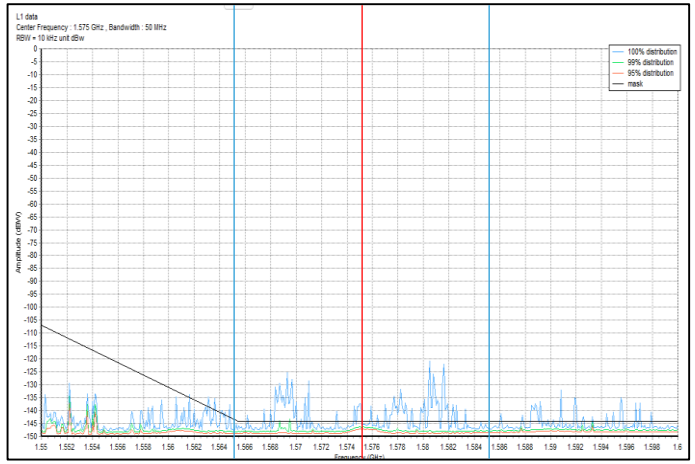
GPS L5 (In/Near band)
(@Cheongju site)

CW interference thresholds
for GPS L1/L2/L5

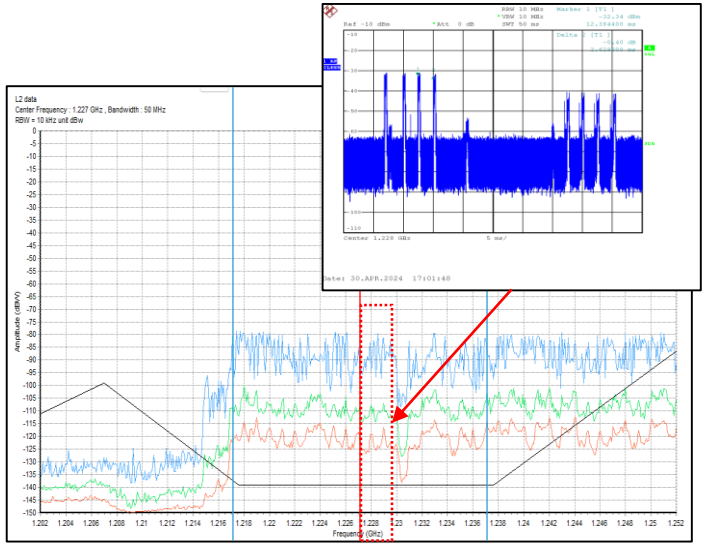
GNSS signal monitoring (from L-Band)

Signal analysis results for GPS L-band (Spectrum analysis) #2

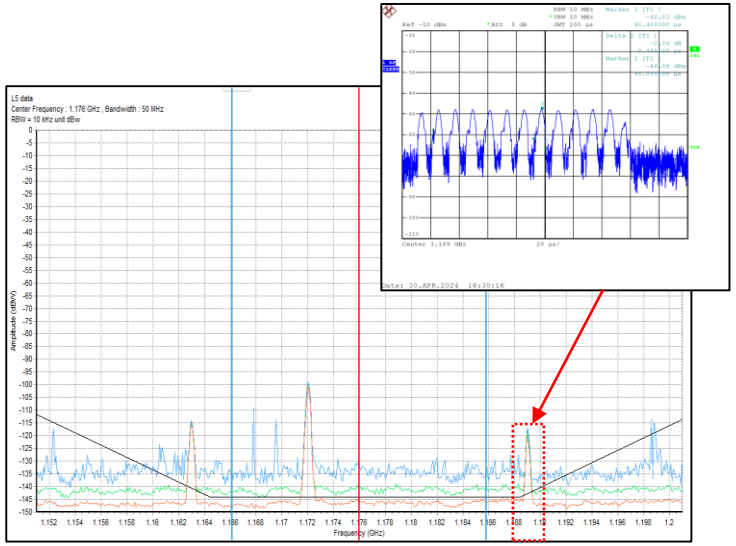
- **If the signal threshold is exceeded, further analyze the pulse width of the interference signal to determine**



GPS L1 (In/Near band)
(@Incheon site)



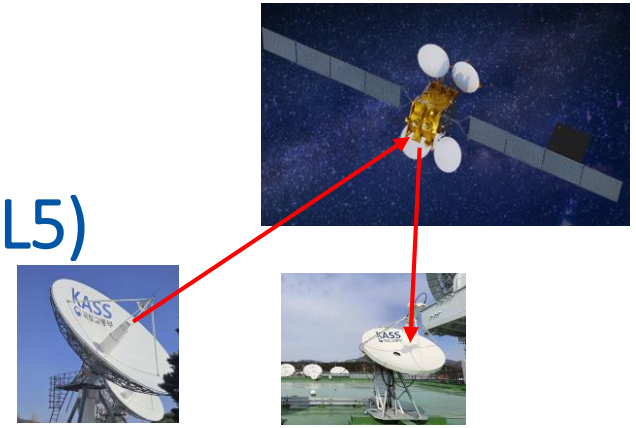
GPS L2 (Pulse - Specific frequency)
(@Incheon site)



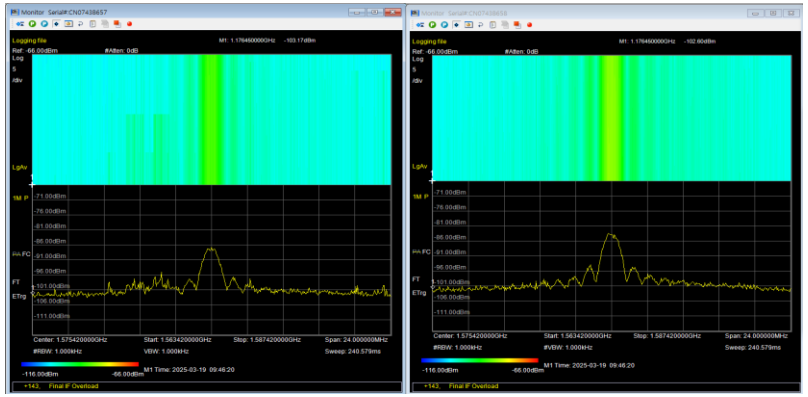
GPS L5 (In/Near band)
(@Incheon site)

GNSS signal monitoring (from KASS GEO L1/L5)

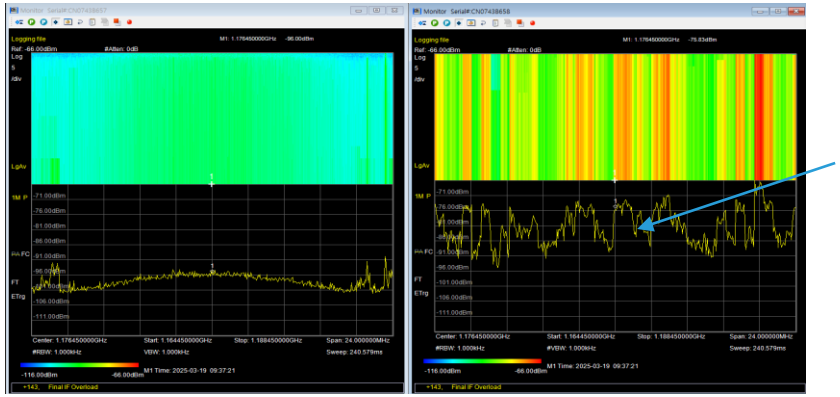
Real time monitoring & Analysis



- **KASS GEO#1 provides SoL service using the L1 band.**
- **In the band surrounding the GEO L5 center frequency(1176.45 MHz) has a lot of interference signals by time and region.**
- **In particular, it is affecting KUS' Steering chain, which transmits data to KASS GEO satellites.**
  - **Due to an increase in the signal noise ratio of the GEO L5 signal, the steering chain is cut off and switched to a backup SGS.**



Geumsan and Yeongju's GEO L1 spectrum
(Center Freq.:1575.42 MHz, Span: 24MHz, MAXHOLD)



Geumsan and Yeongju's GEO L5 spectrum
(Center Freq.:1176.45 MHz, Span: 24MHz, MAXHOLD)

GNSS signal monitoring (from KASS GEO L1/L5)

GNSS signal analysis in the area of interest

(GNSS L1/L5 from KRS)

- **Jamming and Spoofing signals were not detected due to geographic blocking of KRS in the area of interest.**

(KASS GEO L1/L5 form KUS)

- **Normally, there is no problem in transmitting(C1, C5) and receiving(L1, L5) signals between the KUS and KASS satellites.**
- **Intermittent RFI intrusion into the KASS GEO L5 signal occurs, and when strong and with a wide bandwidth, signal dropouts occur. (In this case, switch to automatic backup)**

KASS Operating Procedures (Regarding GNSS RFI Occurrence)

Operational procedures in abnormal situations

❖ KASS operation procedure according to GNSS RFI detection

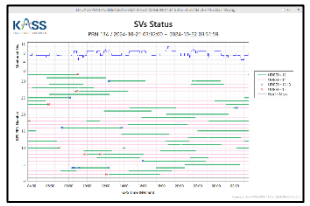
Receiving GNSS RFI information from external agencies

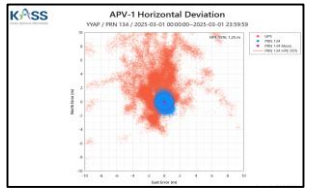
From Central Radio Management Service or Ministry of Science and ICT or NOTAM service

Central Radio Management Service

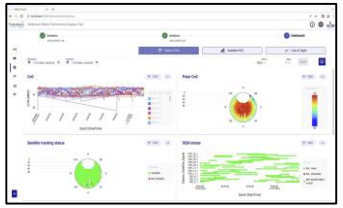
Ministry of Science and ICT

Analysis if KASS performance is abnormal





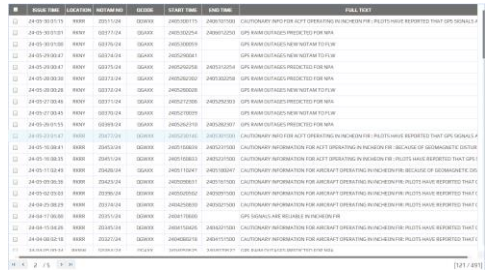
Analysis nearby KRS or others RS data from RFI sources



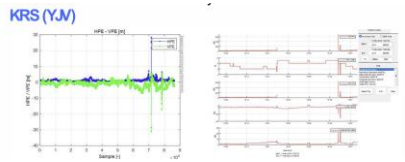
Notification of normal operation

Analysis of the impact of services

Issue NOTAM Notice to Aviation Industry



KASS Real-time Anomaly Detection



Analysis if KASS performance is abnormal

Analysis nearby KRS or others RS data from RFI sources

Normal operation

04

Conclusion

Conclusion

- The number of GNSS RFIs within the INCHEON FIR in South Korea is increasing, and there is an increase in RFI-related reports near airports(Incheon & Kimpo airport) in the northern part of South Korea.
- GNSS RFI needs to be monitored because it affects not only aviation but also various fields including maritime affairs.
- South Korea's radio monitoring agency, which monitors GNSS RFI, is also increasingly detecting the influx of strong interference signals.
- To ensure safer aircraft navigation, we are strengthening real-time monitoring of jamming and spoofing and developing response procedures.
- We are also supporting academic and industrial research on anti-jamming and anti-spoofing.
- GNSS RFI is a major obstacle to transitioning to next-generation navigation system. Therefore, sharing of experiences, including solutions among countries, is necessary.

Thank You

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