

# Development and Operation of a GPS Jammer Localization System at the Airport



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# Backgrounds

## ❖ GPS jamming cases in Korea

- 4 cases after 2010

	1 <sup>st</sup> (2010.8.23~26)	2 <sup>nd</sup> (2011.3.4~14)	3 <sup>rd</sup> (2012.4.28~5.13)	4 <sup>th</sup> (2016.3.31~4.5)
	Western coast area	West border (Near to Seoul) & East border		
Reported Influence	▶181 WCSs	▶145 WCSs	▶64 WCSs	▶1,786 WCSs
	▶15 Aircrafts	▶106 Aircrafts	▶1,015 Aircrafts	▶962 Aircrafts
	▶1 Ship	▶10 Ships	▶122 Ships	▶694 Ships

※ WCS : Wireless Communication Station

# Backgrounds

## ❖ GPS jamming cases in Korea

- Jamming signal was from North Korea

The screenshot shows a news article from channelnewsasia.com. The article title is "GPS jamming signals hit S.Korea jets" and it is dated "Posted: 03 May 2012 10:51 hrs". The text of the article includes:

SEOUL: Electronic jamming signals from North Korea which have affected scores of civilian flights in South Korea were continuing unabated on Thursday, officials said, amid simmering cross-border tensions.

"GPS (global positioning system) jamming signals are continuing this morning," Son Dong-Hwan, a transport ministry deputy director, told AFP.

As of 9:00 am (0000 GMT, 8.00 am Singapore time), a total of 319 aircraft had been affected since Saturday, he said. "But it poses no threat to navigational safety."

The state Korea Communications Commission said the signals were coming from a city just north of the border.

"We've traced the jamming signals to the direction of **Kaesong**," said Lee Kyung-Woo, a commission deputy director.

The article also features a map of the Korean peninsula with a red arrow pointing to Kaesong, North Hwanghae, North Korea. Other locations marked on the map include P'yongyang and Seoul. A small inset image shows a soldier in a military uniform looking through binoculars.

Additional elements in the screenshot include the channelnewsasia.com logo, a navigation menu on the left, and various social media sharing buttons (Facebook, Twitter, LinkedIn, etc.).



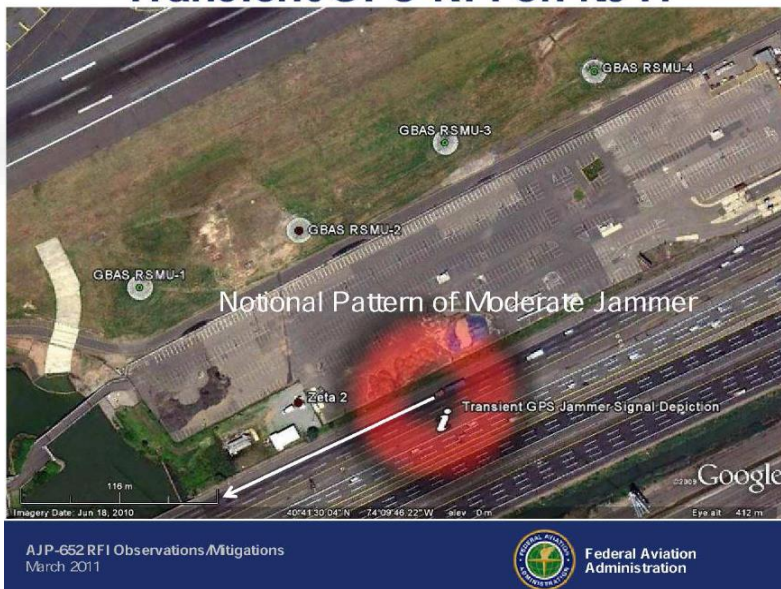
# Backgrounds

## ❖ GPS jamming cases in other countries

- Newark airport in 2010
  - LGF(LAAS Ground Facility) was jammed
  - From PPD(Personal Privacy Devices)



### Transient GPS RFI on NJTP



### Difficult to Detect and Isolate

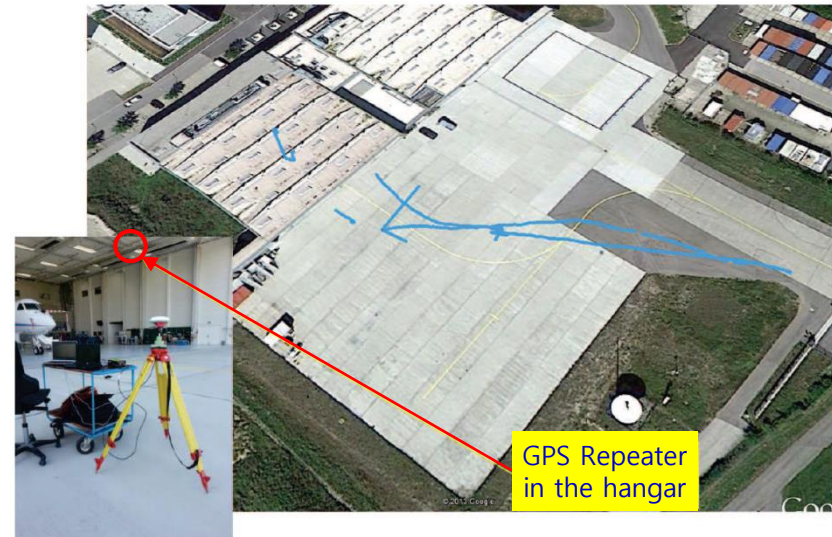
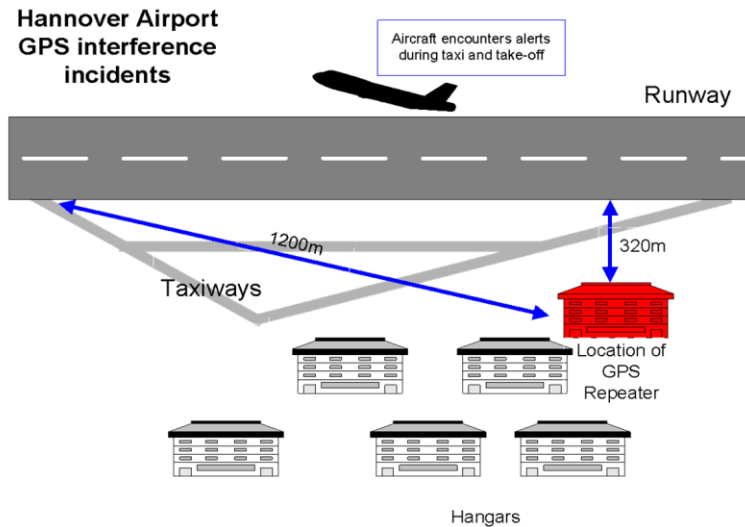


Courtesy of John Warburton and Carmen Tedeschi, "GPS Privacy Jammers and RFI at Newark," IGWG12, November 2011.

# Backgrounds

## ❖ GPS jamming cases in other countries

- Hannover airport in 2010
  - Enhanced Ground Proximity was jammed
  - Due to the GPS repeater



Courtesy of ICAO Information Paper ACP-WGF23/IP-21

# Backgrounds

## ❖ Countermeasures for GPS jamming/interferences

- A/J techniques in a GPS receiver

- Array antenna techniques
- Digital filtering techniques

- Integrated systems


- ILS (Instrument Landing System)
- DME (Distance Measuring Equipment)
- VOR (VHF Omni-directional Range)

- Monitoring systems

- IDM (Interference Detection & Mitigation)
- CORS (Continuously Operating Ref. Station)

- Localization system

- Detection & Localization



Not sufficient to guarantee **accuracy**



Guarantee only **integrity**

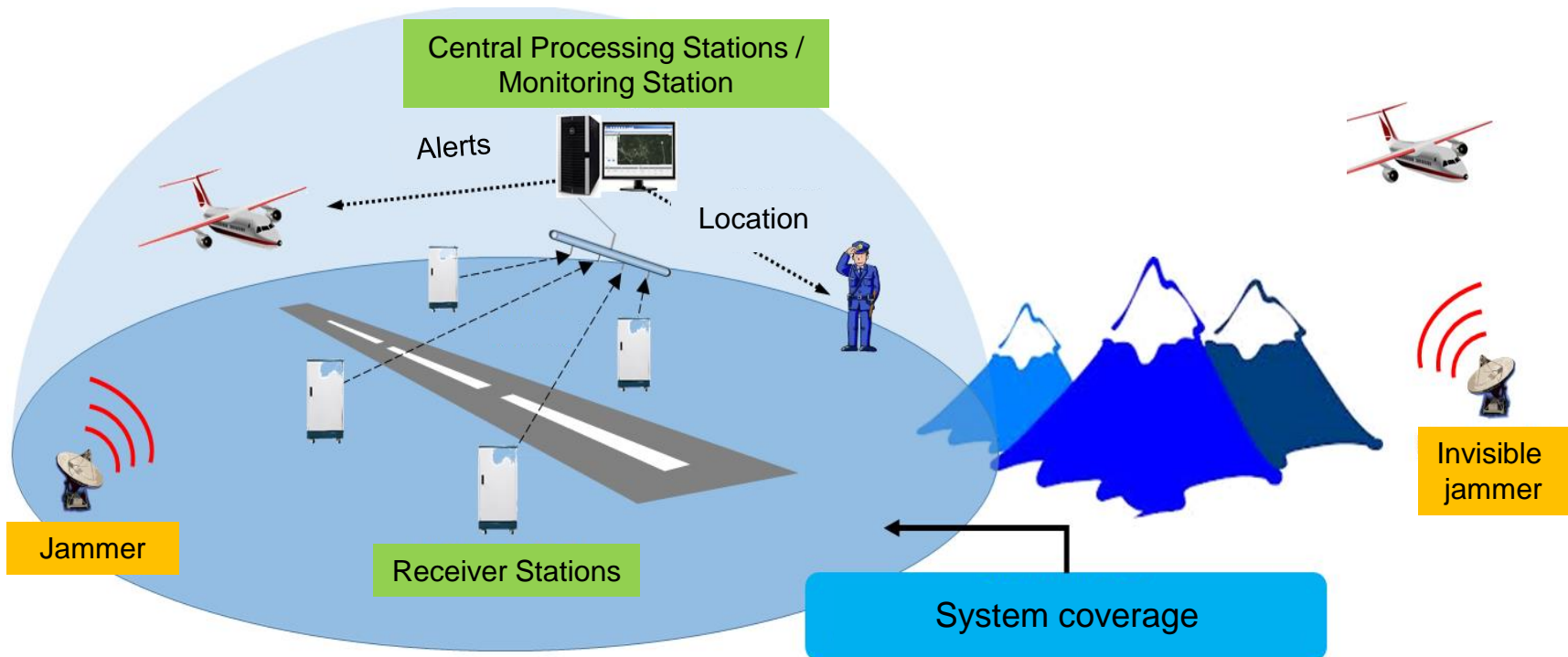


Guarantee **integrity/continuity**

# System Design

## ❖ System Description

- Prototype
- 4 Receiver Stations, a Central Processing Station, a Monitoring Station



<Concept of a jammer localization system>

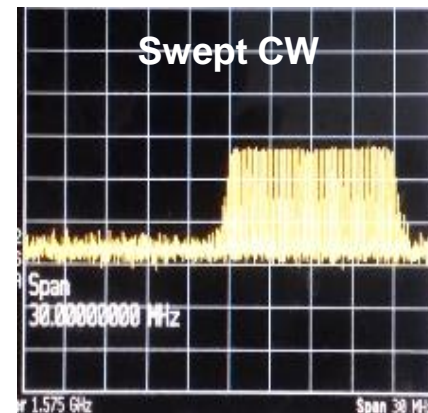
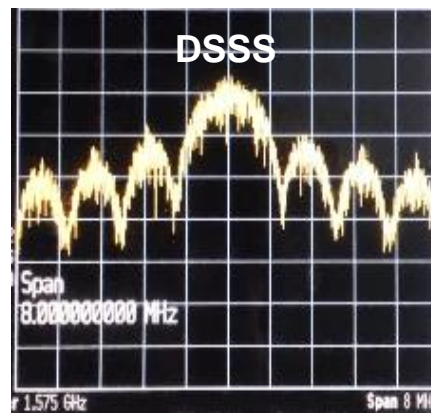
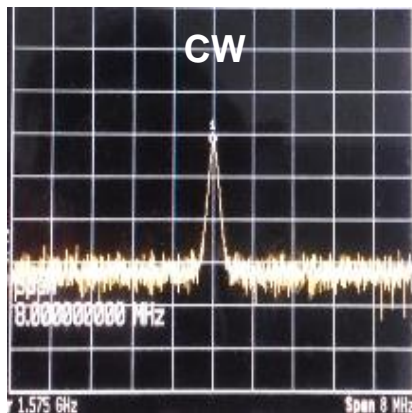


# System Design

## ❖ System Specifications

System Performance	
Accuracy	< 50 m (CEP), for a jammer located at 10km away
Detection time	< 6 s
Sensitivity	-107 dBm

Type of jamming signals	
CW	- Single tone signal - <b>Used by North Korea mostly</b>
DSSS	- GPS-like signals - <b>Used at Hannover airport</b>
Swept CW	- Frequency varying CW signal - <b>Used at Newark airport</b>



# System Design

## ❖ Algorithms

- Features of algorithms for localization

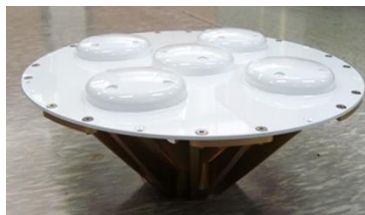
Algorithm	Accuracy	Complexity	Limitations
TOA (Time of Arrival)	Good	Moderate	Not applicable to unknown signals
RSSI (Received Signal Strength Identification)	Not that accurate	Low	Not applicable to unknown signals
AOA (Angle of Arrival)	Adequate	High (Array antennas and RF circuits)	Heading of array antennas of each receivers should be aligned
TDOA (Time Difference of Arrival)	Good	Moderate	Clocks of each receivers should be synchronized
RSSD (Received Signal Strength Difference)	Not that accurate	Low	Relatively high receiver power

# System Development and Installation

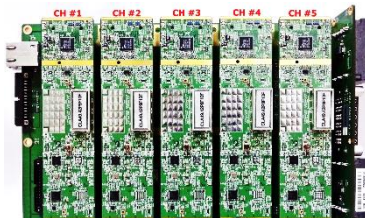
## ❖ Development

### ■ Receiver Station

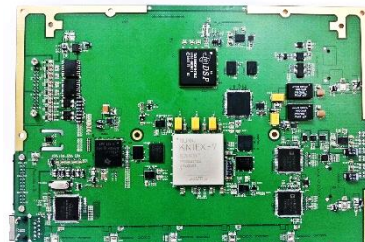
- Includes array antenna, RF/IF and digital circuits and other sensors



Array antenna



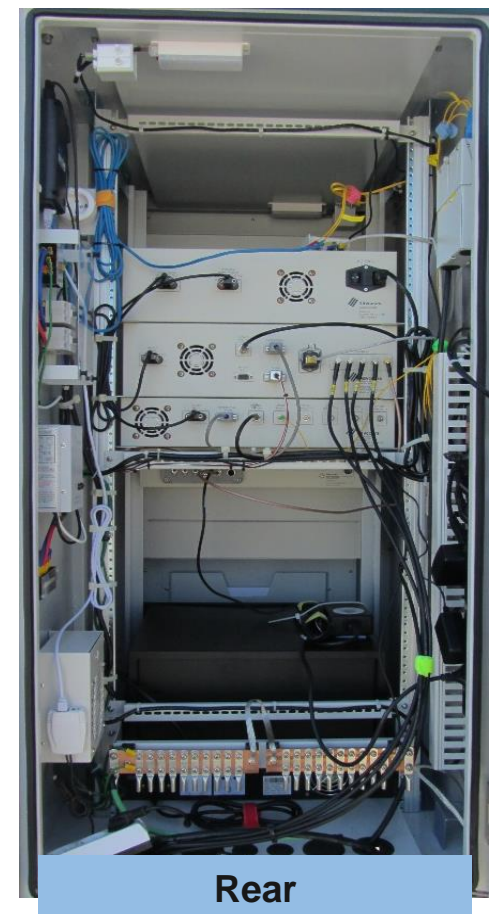
RF/IF Circuits



Digital Circuits



Front



Rear

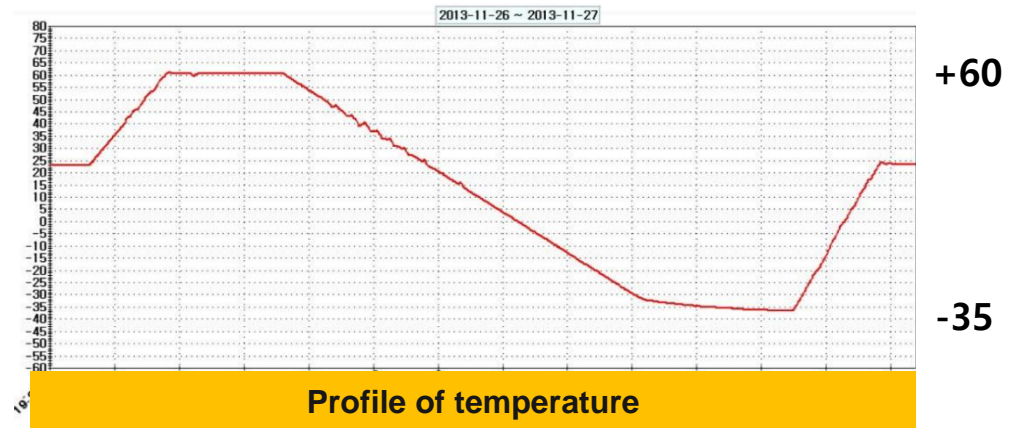
# System Development and Installation

## ❖ Development

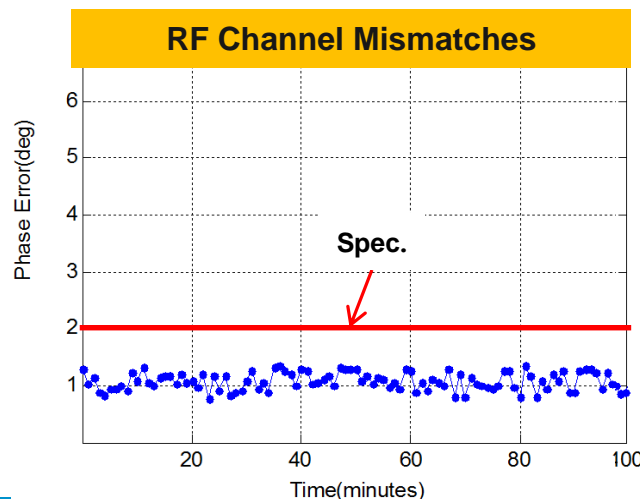
- Verification of functionality
- Verification of RF channel mismatches in RF/IF circuits



Temperature Chamber



Profile of temperature



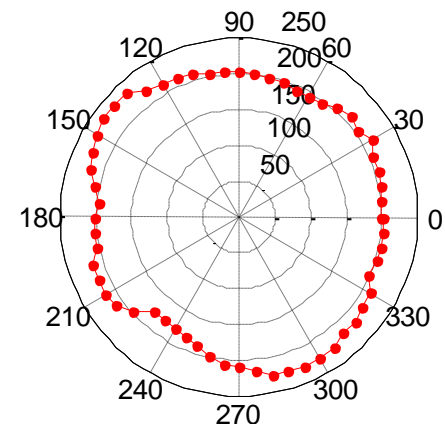
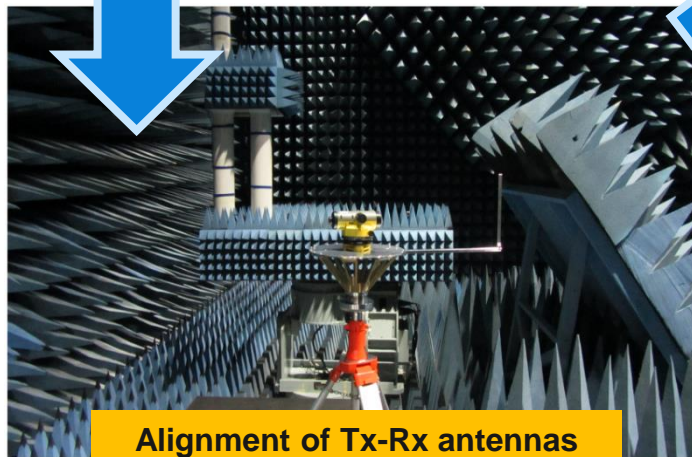
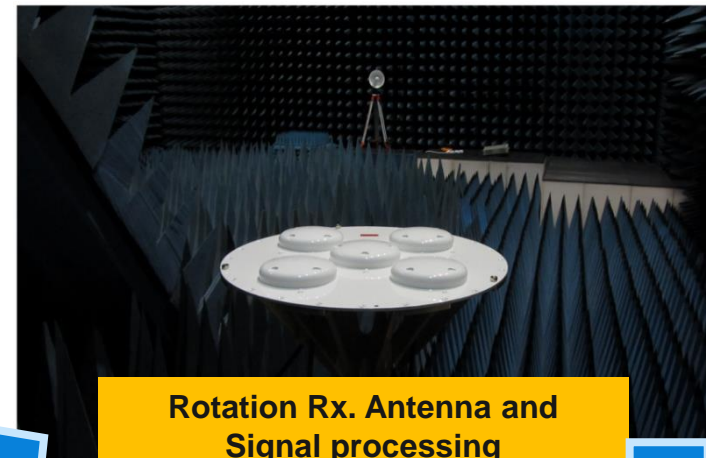
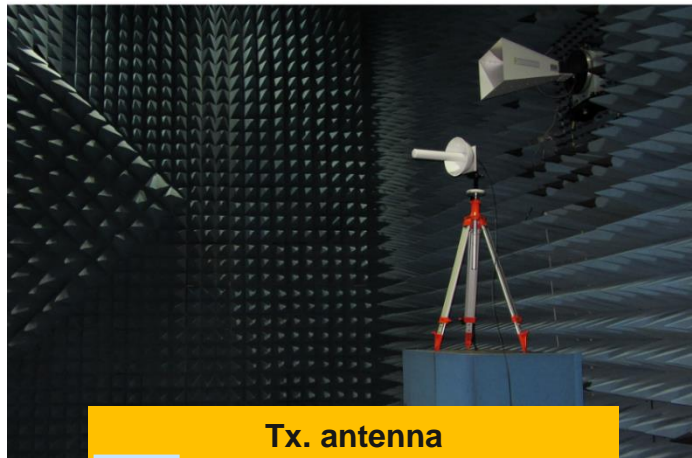
Channel mismatch error:  
1.2 deg. (rms)



# System Development and Installation

## ❖ Development

- Measuring antenna mismatches in an anechoic chamber

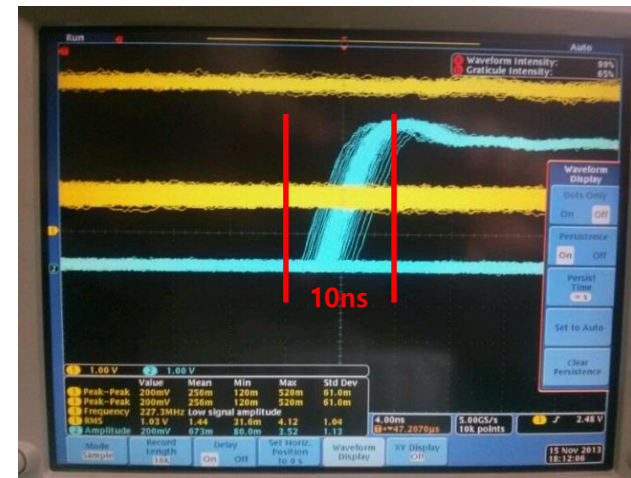
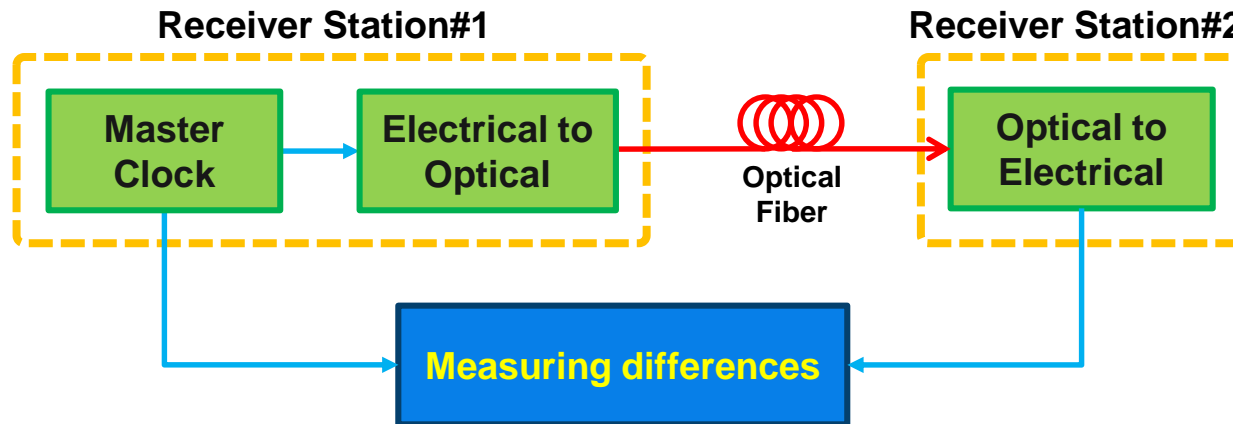




# System Development and Installation

## ❖ Development

- Performance of time synchronization between Receiver Stations



**Time sync. error : 4.8ns (rms)**

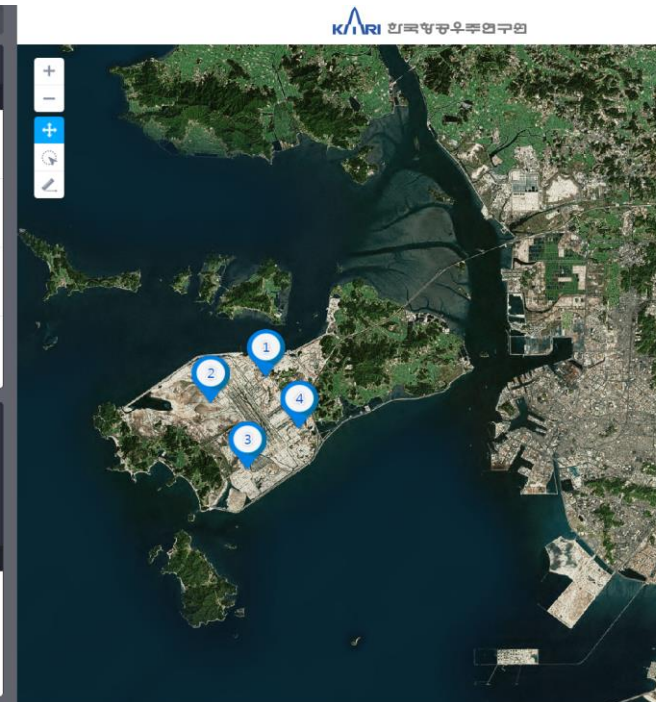
# System Development and Installation

## ❖ Development

- Central Processing Station
  - Includes Linux servers for algorithm processing and web-browser
- Monitoring Station



Sever rack



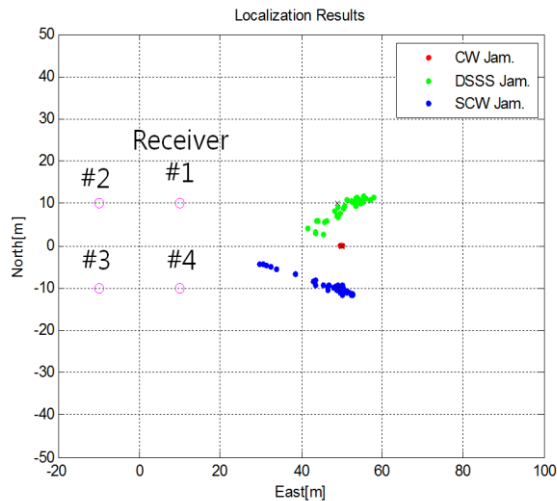
Web-browser



# System Development and Installation

## ❖ Development

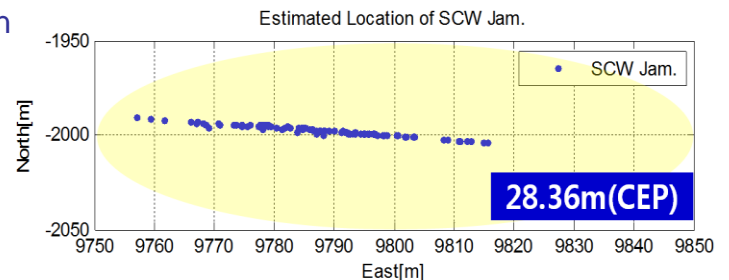
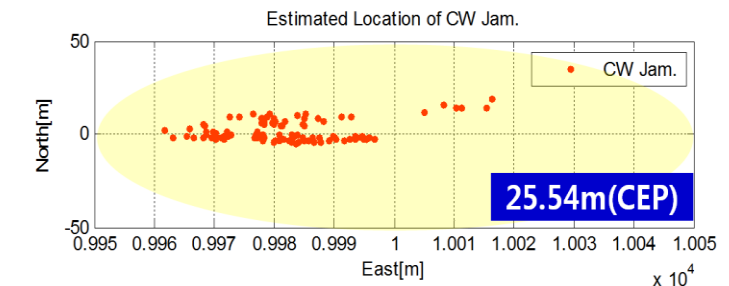
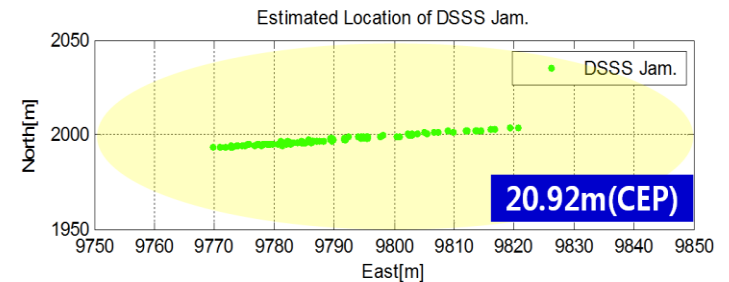
- System verification in indoor environment



<The localization results in 1/200 scale down and real-time environment>



Applying measurement error in real environment



<The expectation results of positioning in real environment>

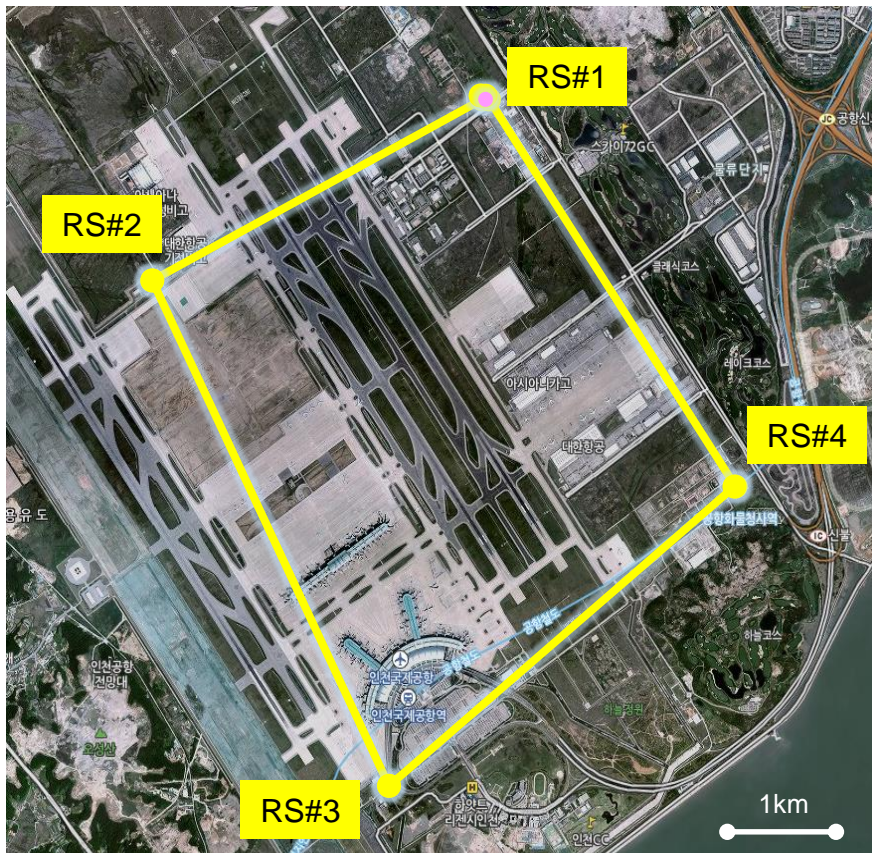


# System Development and Installation

## ❖ Installation

- In Incheon International Airport in Nov. 2014

### Locations of Receiver Stations



### Installation of Rack and Ant.



# System Development and Installation

## ❖ Installation

- In Incheon International Airport in Nov. 2014

### Central Processing Station and Monitoring Station



Central Processing Station



Monitoring Station

### Network for Time Sync.

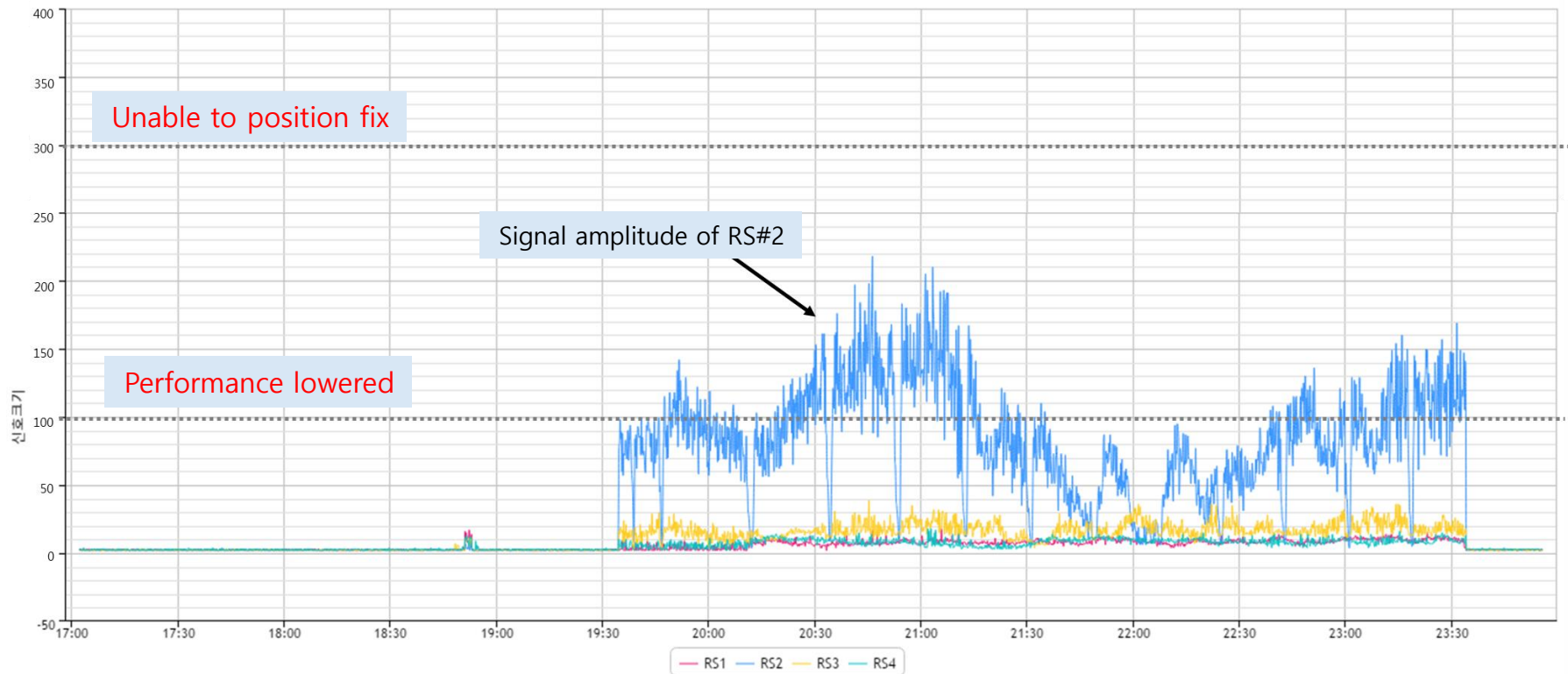




# Operation Results

## ❖ Case Analysis

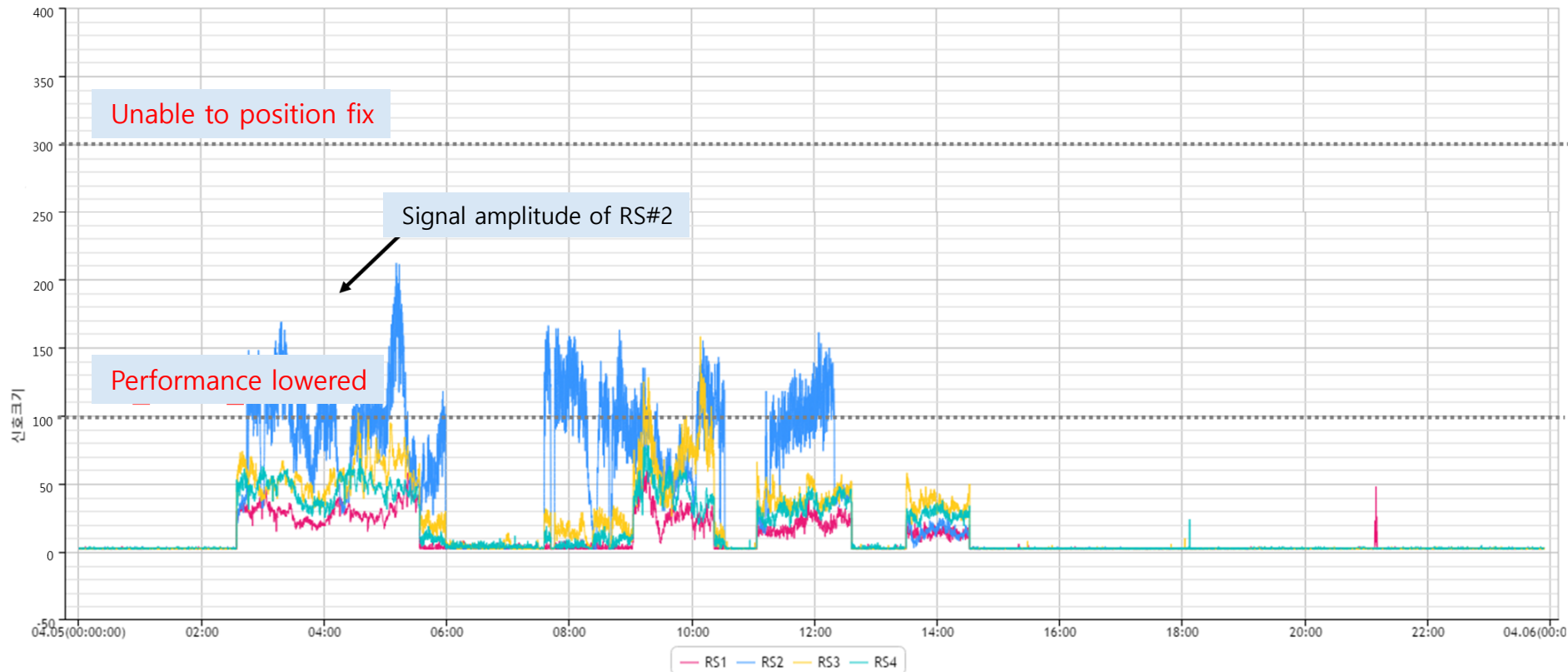
- Signal amplitude on Mar. 31, 2016
  - Since 19:35, jamming signal was detected
  - Signals received at RS#2 were stronger than the others



# Operation Results

## ❖ Case Analysis

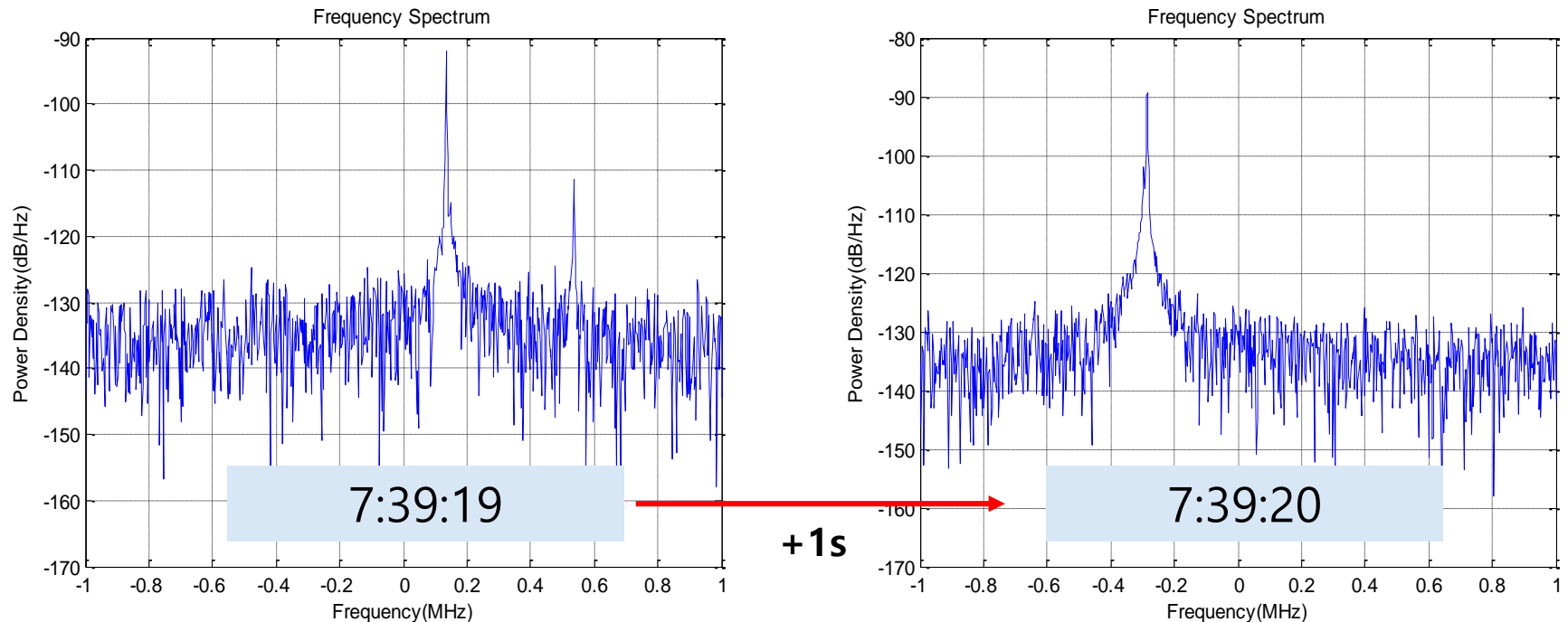
- Signal amplitude in Apr. 5, 2016
  - Ended after 14:30



# Operation Results

## ❖ Case Analysis

- Characteristics of jamming signal
  - Frequency spectrums of signals at 7:38:19 and 7:38:20
  - Jamming signals were time-varying or hopping and with multiple signals



# Operation Results

## ❖ Case Analysis

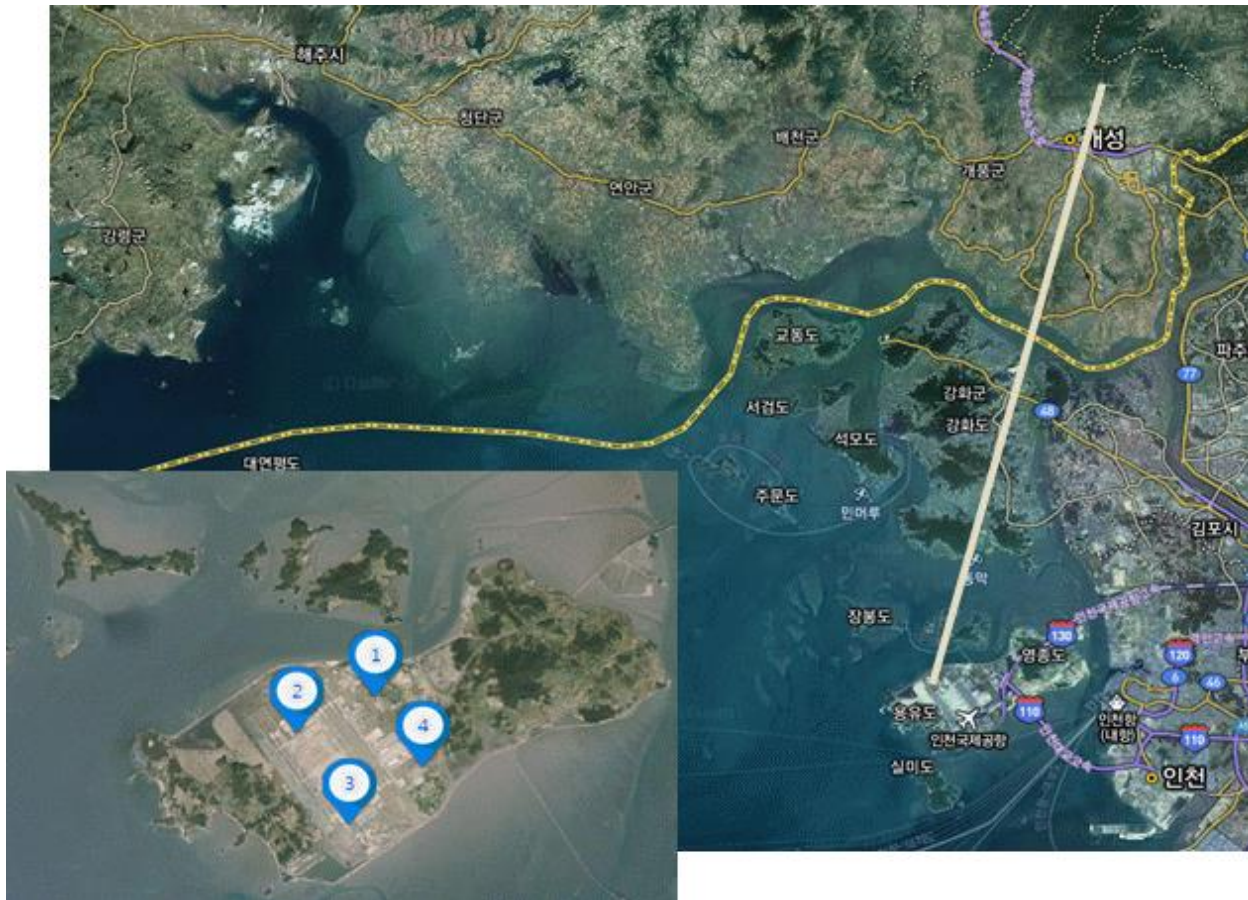
- Estimation of azimuth angle
  - By using the signals of RS#2
  - MUSIC algorithm was operated in post-processing

Date	Mean (deg.)	STD (deg.)
April 1	28.38	1.24
April 2	26.70	0.75
April 3	27.43	0.94
April 4	23.98	1.02
April 5	26.36	1.02

# Operation Results

## ❖ Case Analysis

- Estimation of azimuth angle
  - The azimuth angle indicates Gaesung, North Korea





# Conclusions

## ❖ Summary

- Features of the localization system and algorithms
- Results for the system development, verification, and installation
- Analyzed results for the real jamming case

# Thank you for your attention



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