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

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Contents

Backgrounds

❖ GPS jamming cases in Korea

- 4 cases after 2010

	1st (2010.8.23~26)	2nd (2011.3.4~14)	3rd (2012.4.28~5.13)	4th (2016.3.31~4.5)
Reported Influence	Western coast area	West border (Near to Seoul) & East border		
	▸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

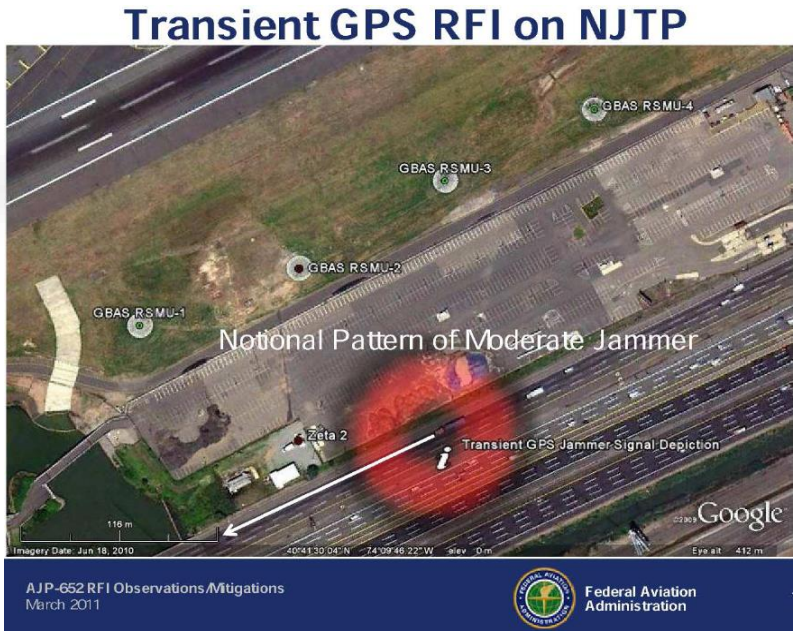
Backgrounds

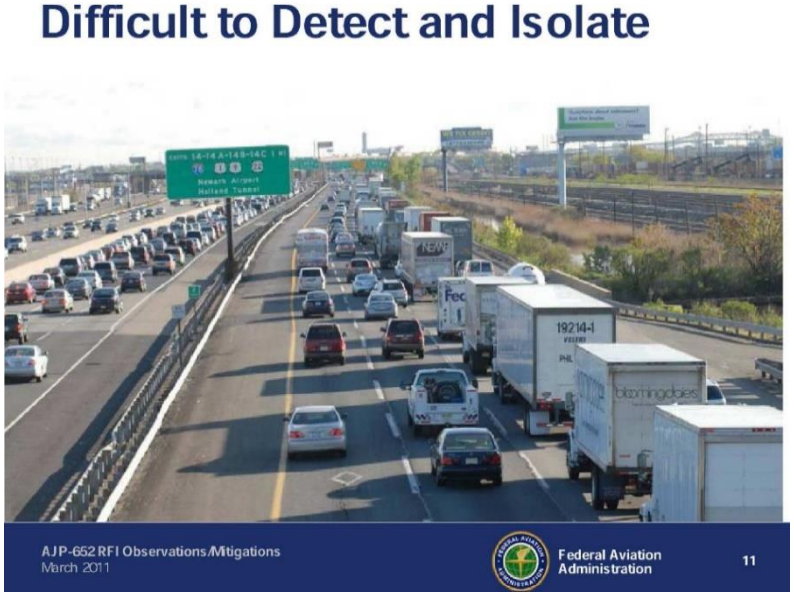
- GPS jamming cases in Korea
  - Jamming signal was from North Korea

Backgrounds

- GPS jamming cases in other countries
  - Newark airport in 2010
    - LGF(LAAS Ground Facility) was jammed
    - From PPD(Personal Privacy Devices)

PPD

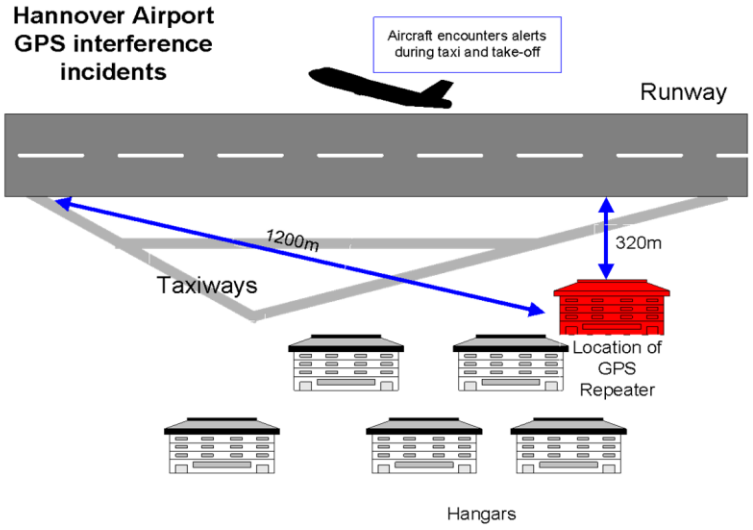


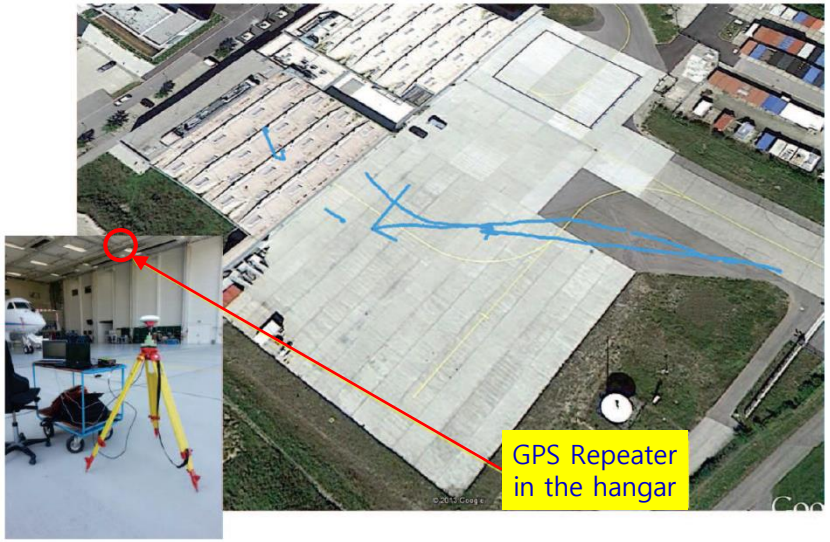


Courtesy of John Warburton and Carmen Tedeschi, "GPS Privacy Jammers and RFI at Newark," IGWG12, November 2011.

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**

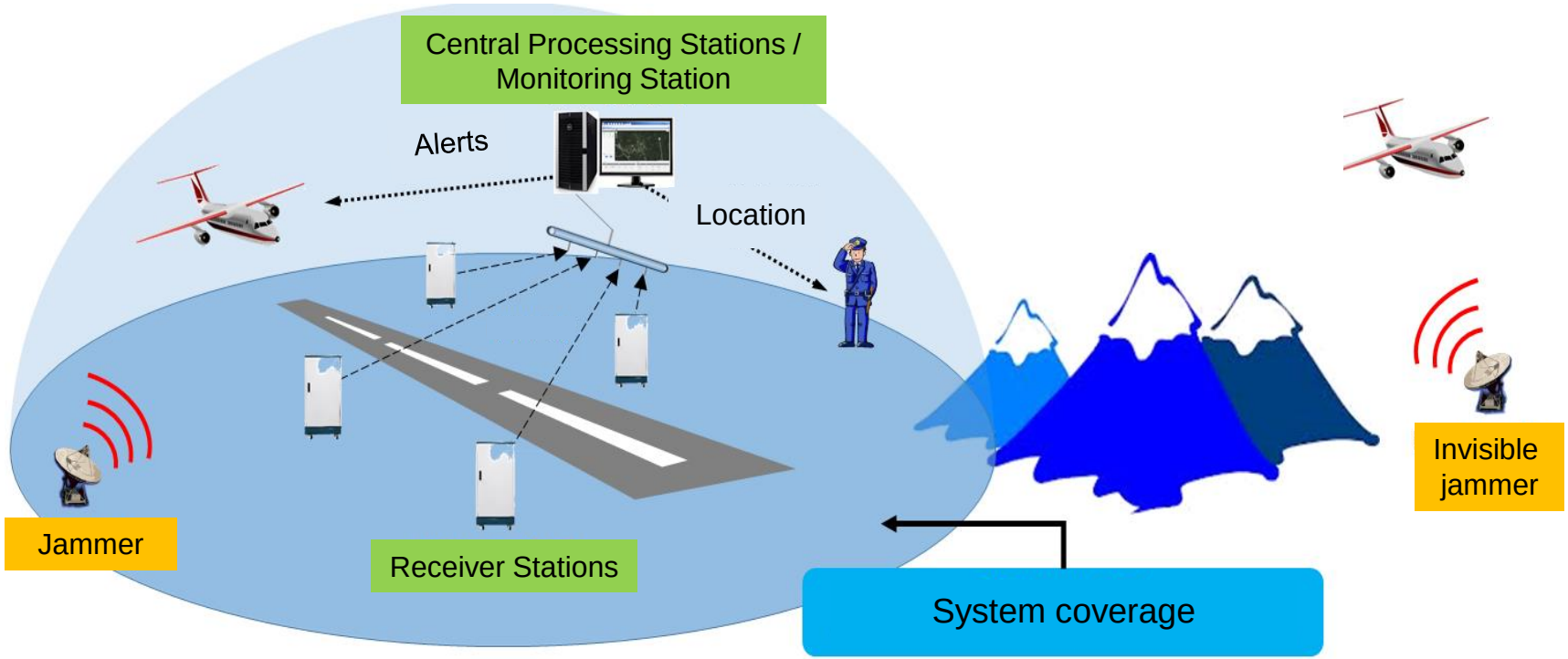
Guarantee only **integrity**

Guarantee **integrity/continuity**

System Design

System Description

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



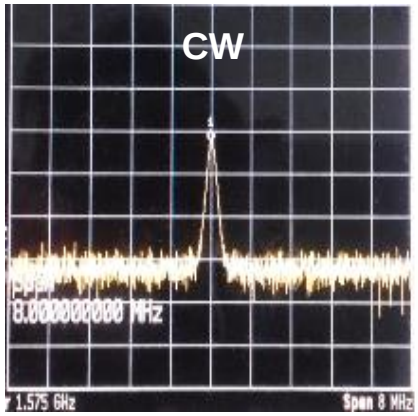
<Concept of a jammer localization system>

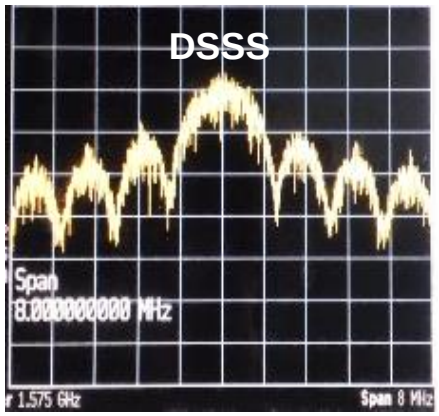
System Design

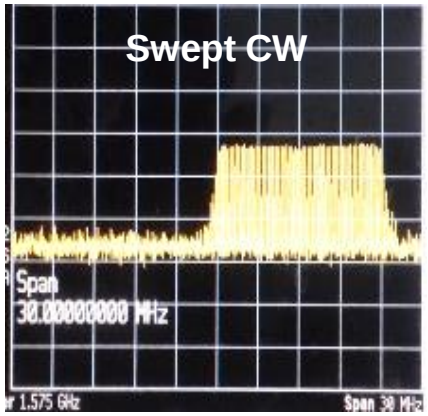
❖ System Specifications

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 - **Used by North Korea mostly**
DSSS	- GPS-like signals - **Used at Hannover airport**
Swept CW	- Frequency varying CW signal - **Used at Newark airport**







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

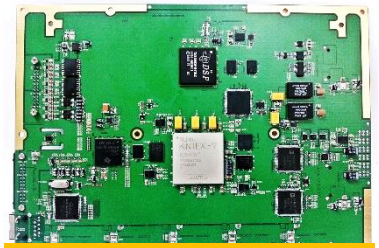
System Development and Installation

❖ Development

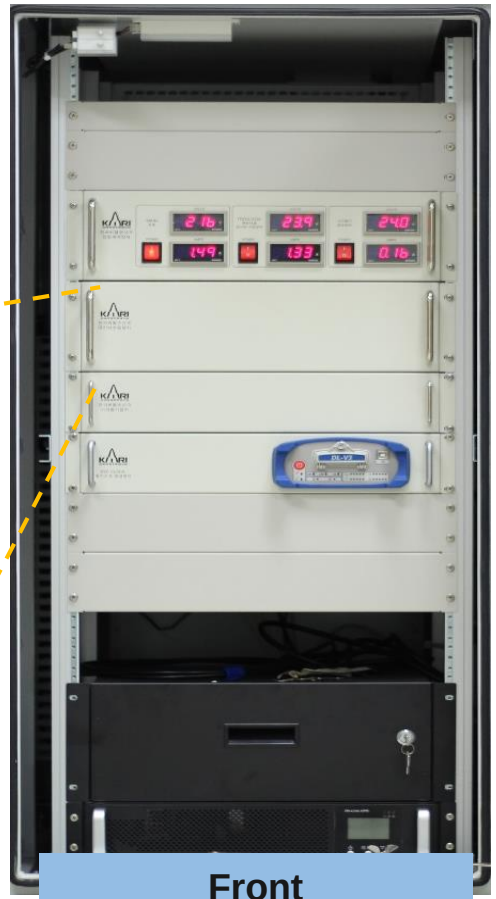
- Receiver Station
  - Includes array antenna, RF/IF and digital circuits and other sensors

Array antenna

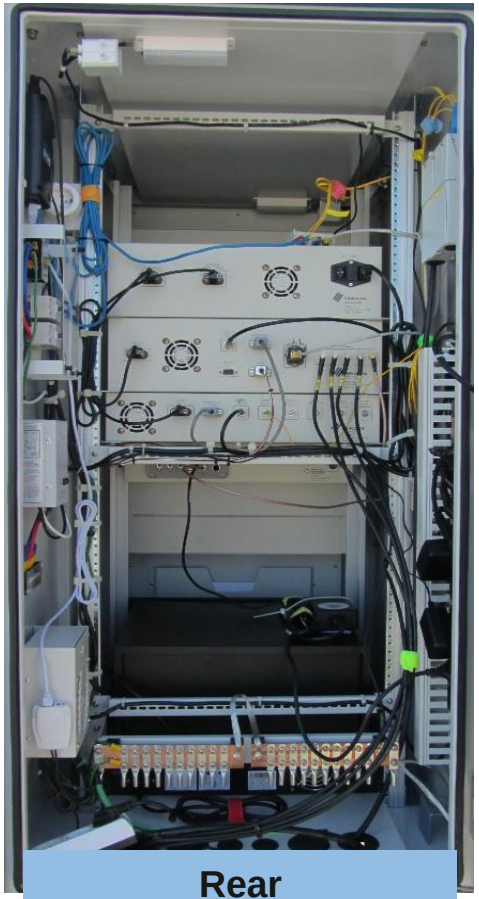
RF/IF Circuits



Digital Circuits



Front



Rear

System Development and Installation

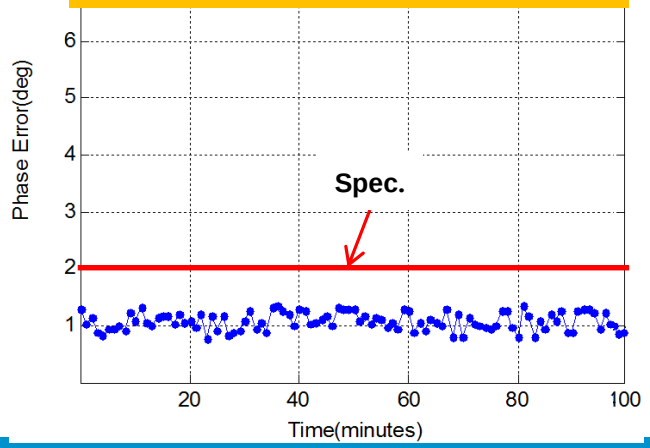
❖ Development

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

Temperature Chamber

Profile of temperature

RF Channel Mismatches

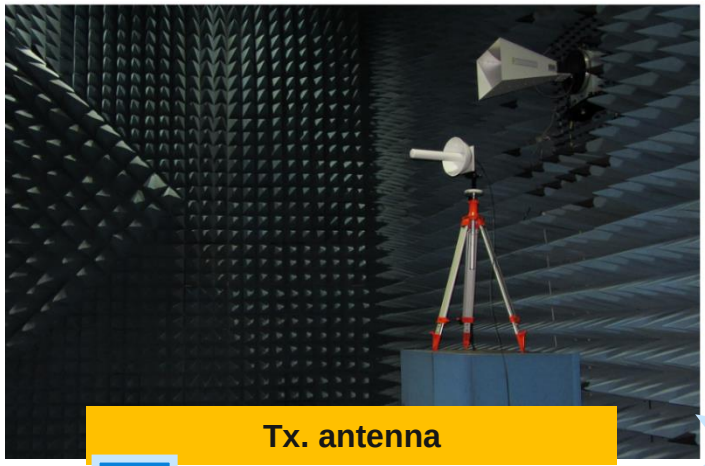


Channel mismatch error: 1.2 deg. (rms)

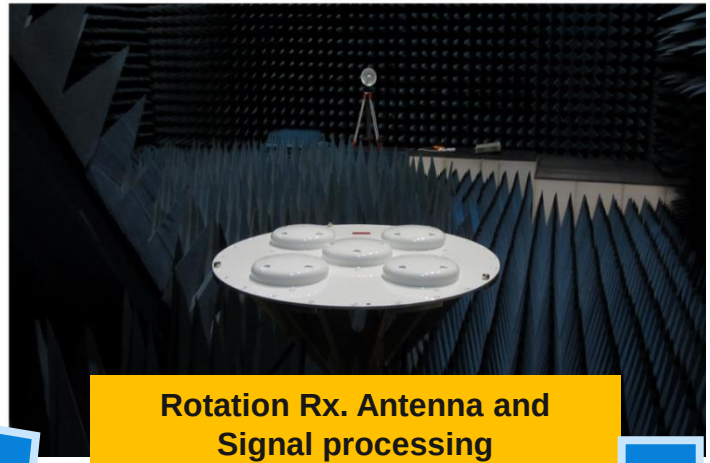
System Development and Installation

❖ Development

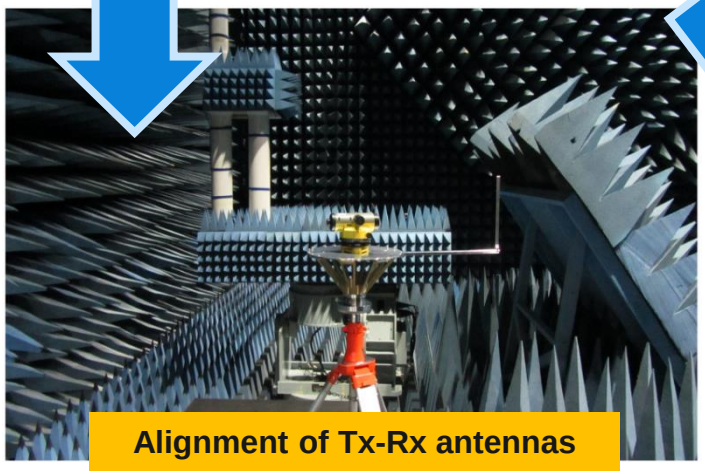
- Measuring antenna mismatches in an anechoic chamber



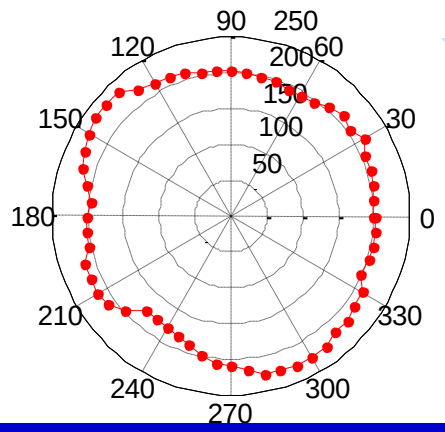
Tx. antenna



Rotation Rx. Antenna and Signal processing



Alignment of Tx-Rx antennas

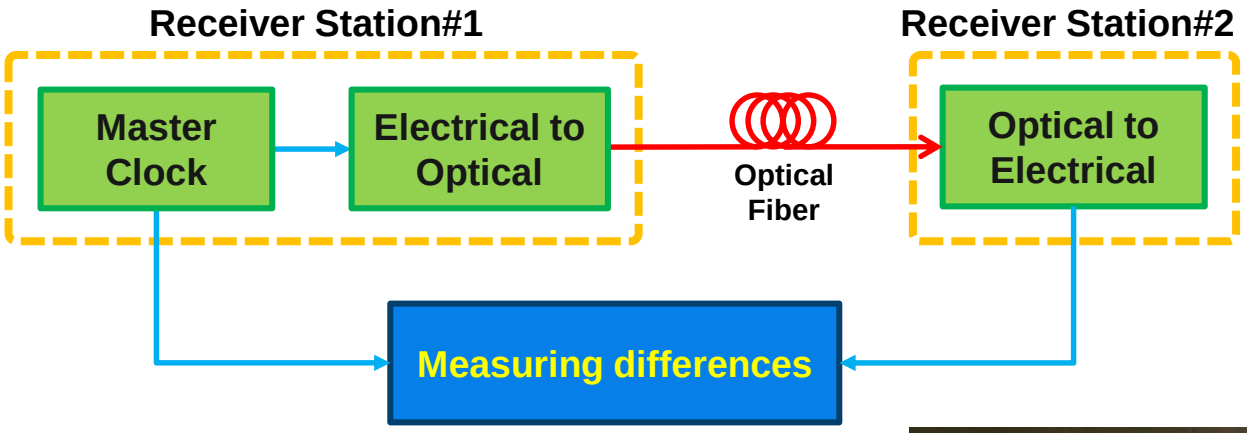


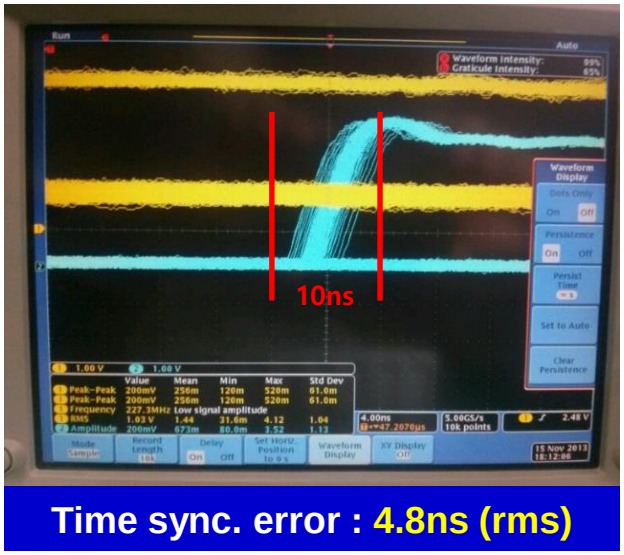
Measuring antenna mismatches

System Development and Installation

❖ Development

- Performance of time synchronization between Receiver Stations





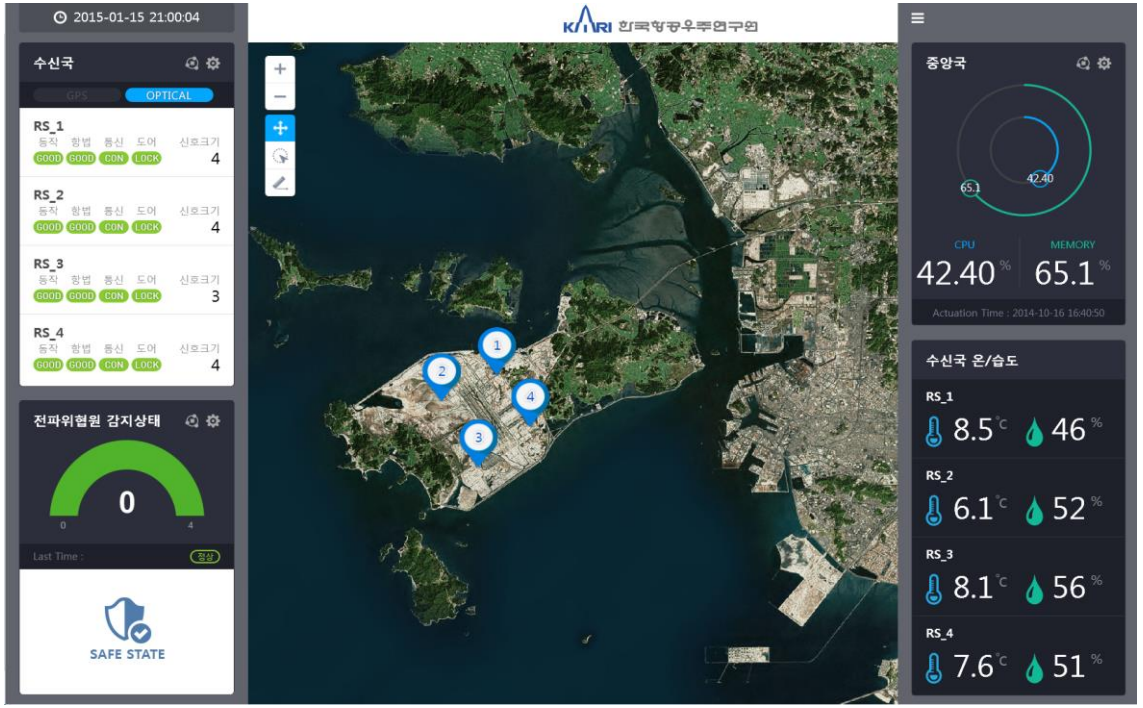
Time sync. error : 4.8ns (rms)

System Development and Installation

❖ Development

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

Sever rack



Web-browser

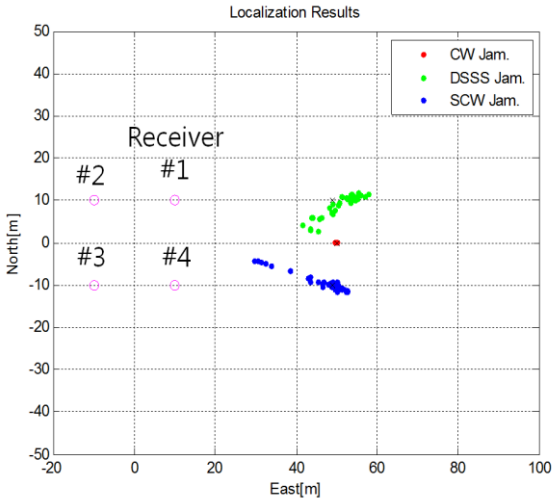
System Development and Installation

❖ Development

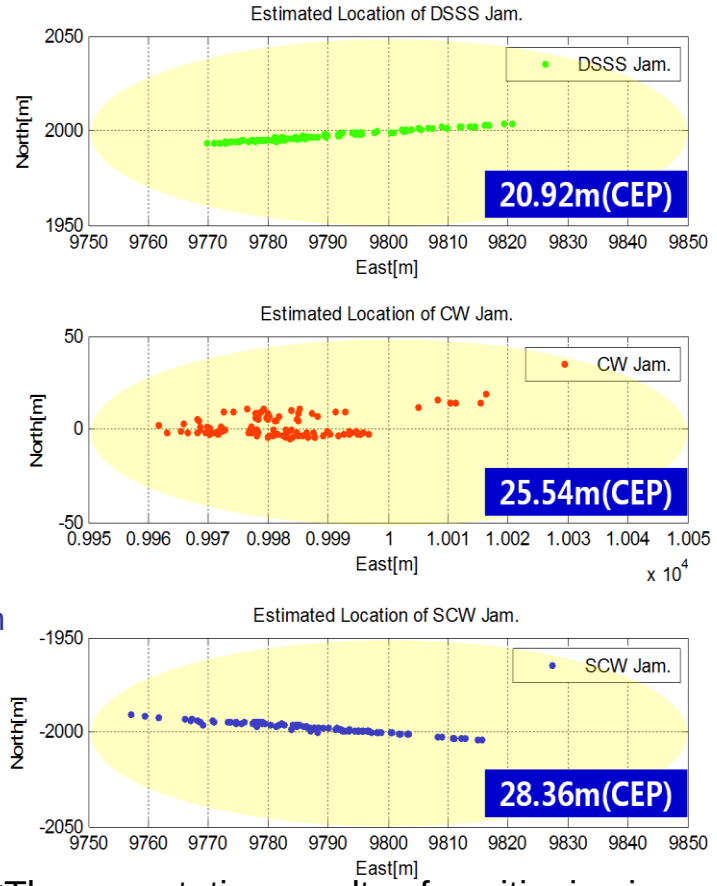
- System verification in indoor environment

Environment Setup

Signal Generator



Applying measurement error in real environment



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

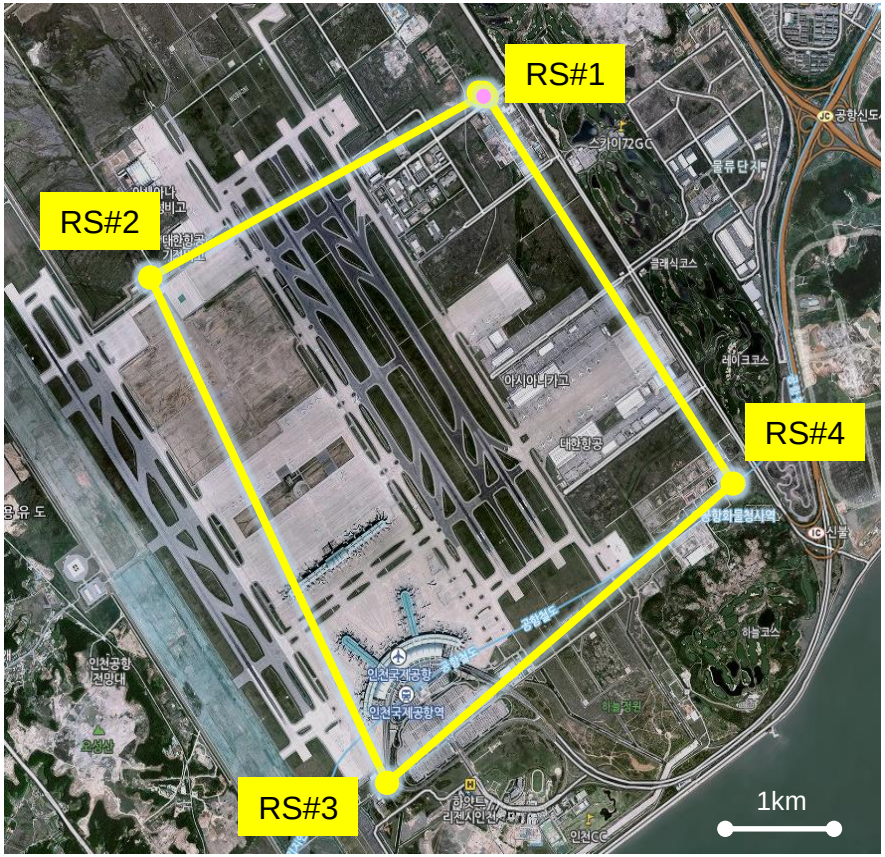
<The expectation results of positioning in real environment>

System Development and Installation

❖ Installation

- In Incheon International Airport in Nov. 2014

Locations of Receiver Stations



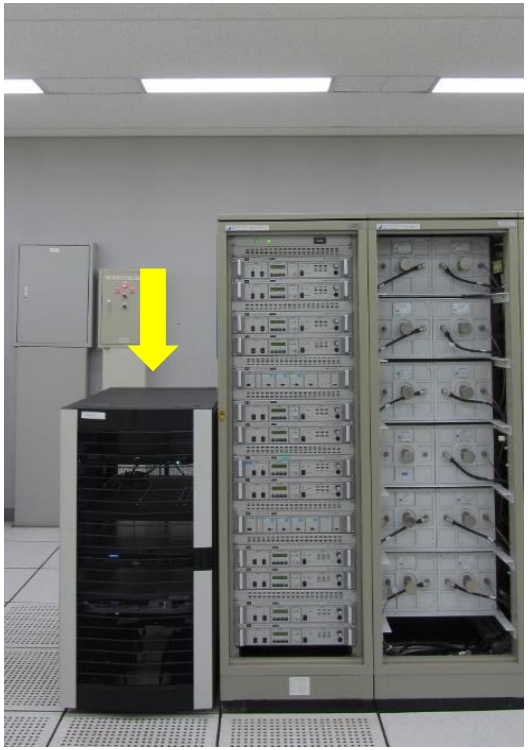
Installation of Rack and Ant.

System Development and Installation

❖ Installation

- In Incheon International Airport in Nov. 2014

Central Processing Station and Monitoring Station



Central Processing Station

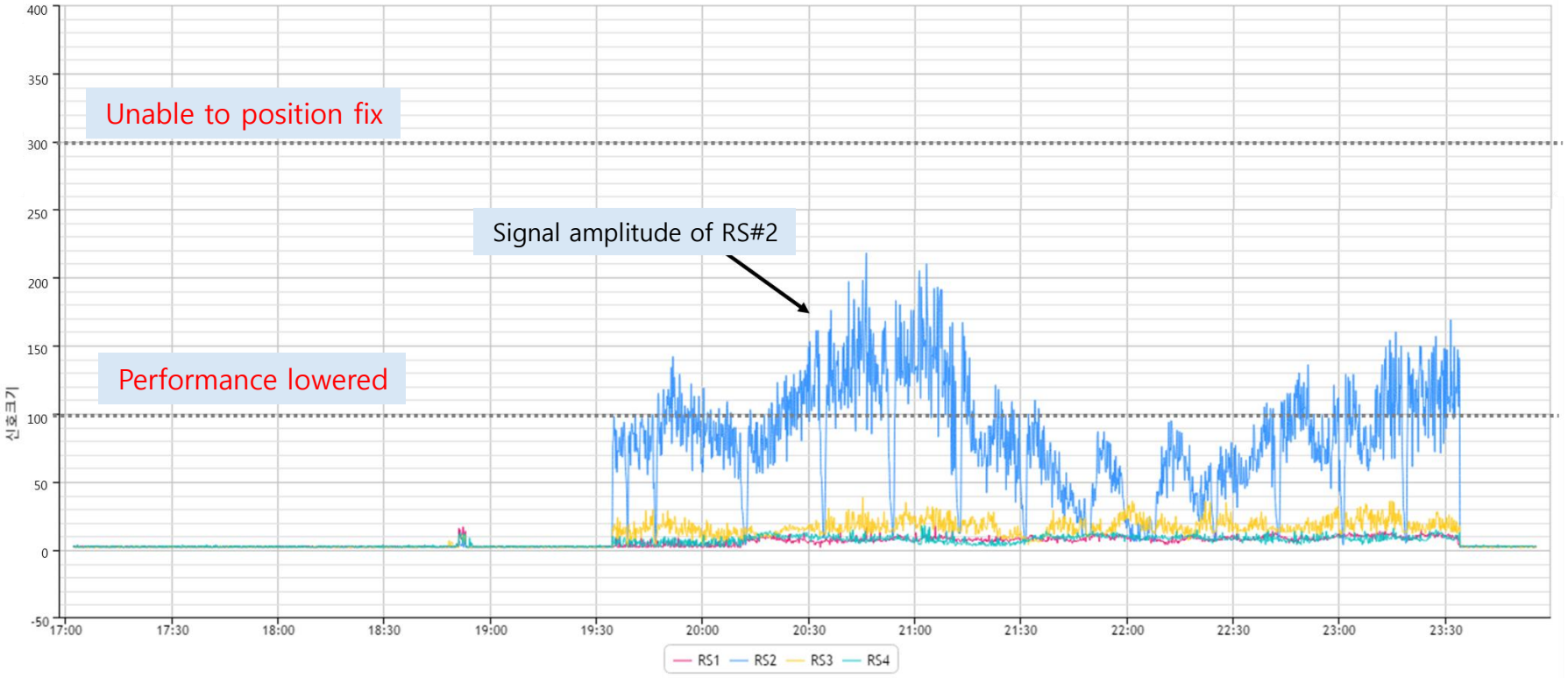
Monitoring Station

Network for Time Sync.

Operation Results

❖ Case Analysis

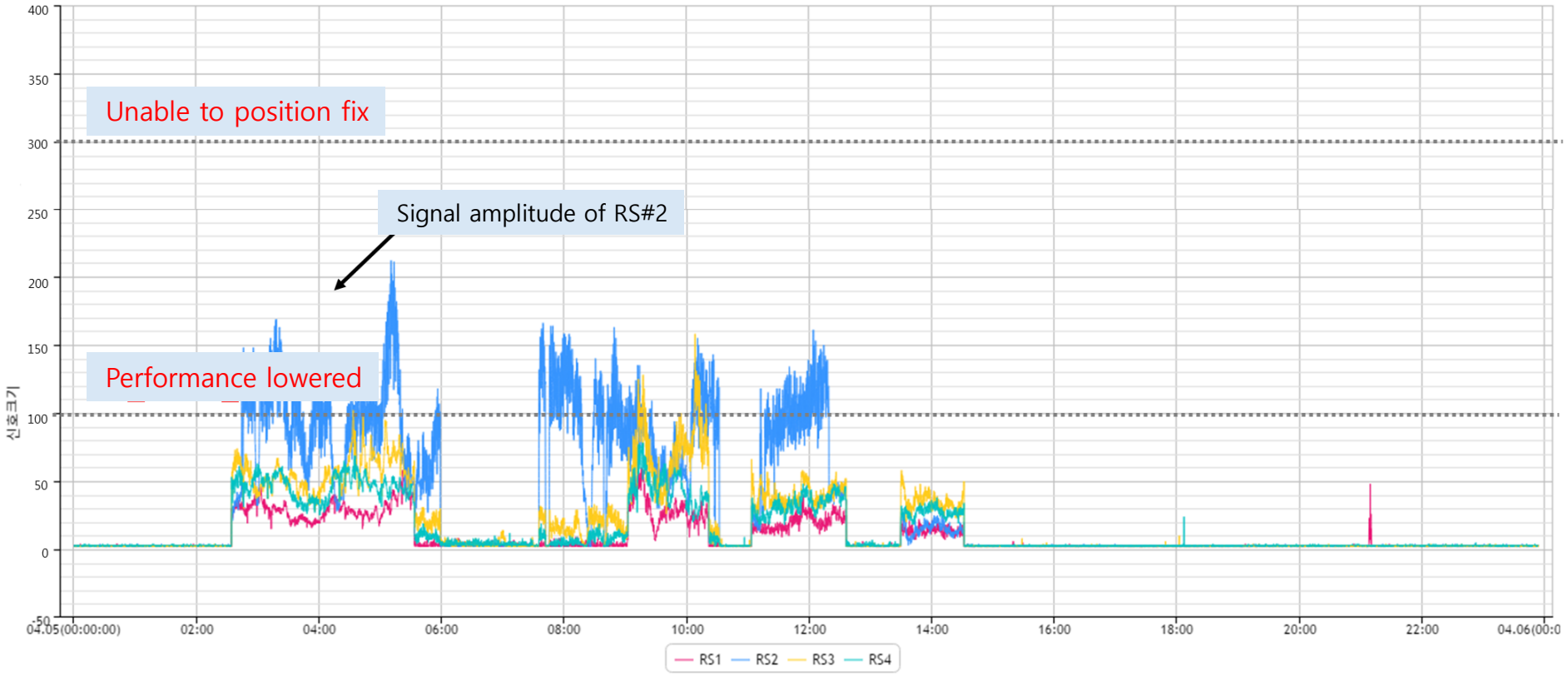
- Signal amplitude on Mar. 31, 2016
  - Since 19:35, jamming signal was detected
  - Signals received at RS#2 were stronger than the others



Operation Results

❖ Case Analysis

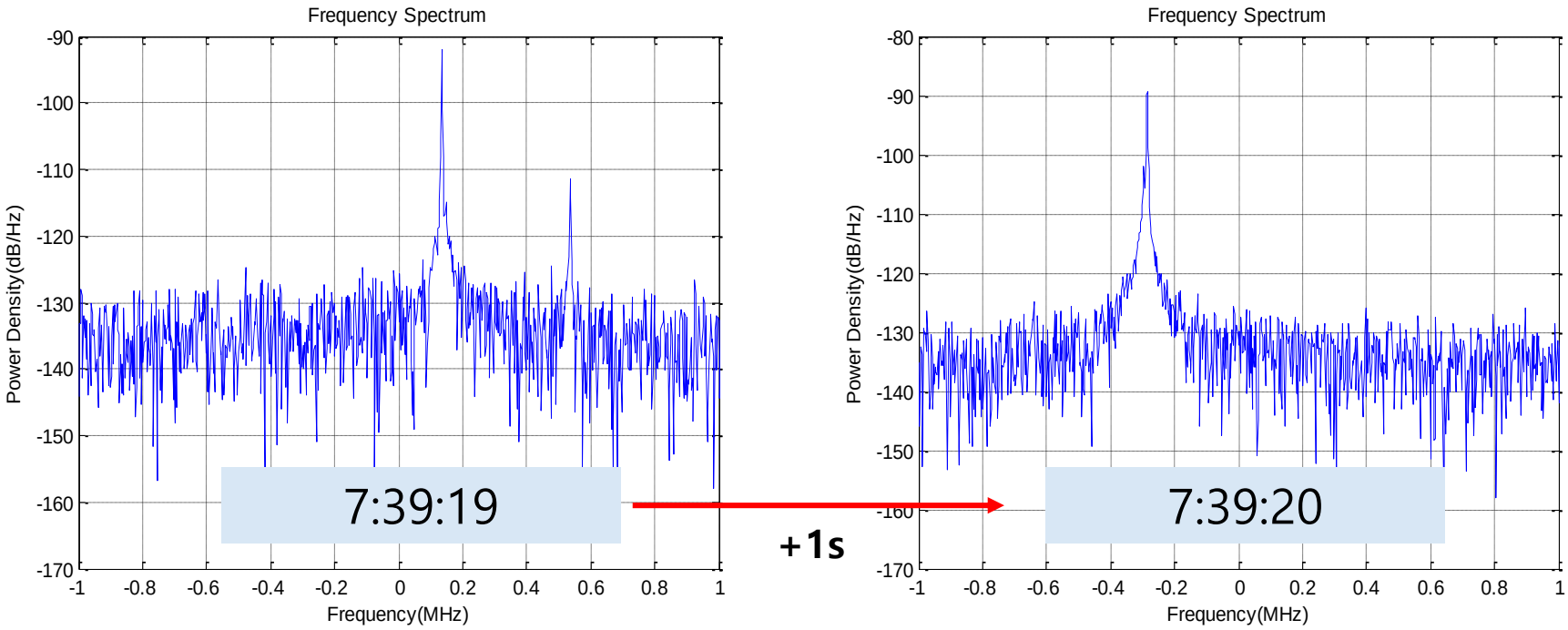
- Signal amplitude in Apr. 5, 2016
  - Ended after 14:30



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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