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Analysis of the Results for the Operation of a GPS Jammer Localization System

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ABSTRACT

In this paper, results of a jammer detection and localization system operation are given. The system consists of receiver stations, a central tracking station, and a monitoring station and it was developed by our institute in 2014. Through real-time tests, it is confirmed that the developed system has an ability to estimate the location of interference sources with an accuracy of 50 m (CEP) even they was 10 km away. After verification, this system was installed in Incheon International Airport and operating results are being monitored by the airport and our institute continuously. In this year, there were some events that jamming signals were received from North Korea, so the data were analyzed and given here.

Keywords: GPS, jammer, localization

1. INTRODUCTION

In order to use global positioning system (GPS)-based navigation equipment in the flight phase of an aircraft especially in the approach and landing, a performance of accuracy, integrity, continuity, and availability should be satisfied. In the case that there are interference or jamming signals, however, the GPS-based navigation equipment cannot provide reliable information. In practice, during initial test of a ground based augmentation system (GBAS) installed at Newark Airport in the United States, jamming signals were detected several times, and thus the operation of GBAS was interrupted for several months. In this regard, the detected jamming signals were transmitted from a personal privacy device which was an equipment used by truck drivers passing the expressway near the airport in order to avoid the tracking of their locations (Pullen et al. 2012). At Hannover Airport in Germany, the pilots flying and taxing near the airport were confused due to the signals of a GPS repeater installed within the hangar. In Korea, there are many reports for the damages in the operation of aircrafts, ships and mobile communication stations near the Seoul metropolitan region because of jamming signals that are known to have been deliberately transmitted from North Korea. Such damages occurred every year between 2010 and 2012, and there was also a report of damages in April 2016.

To cope with jamming signals, monitoring systems have been developed in the United States, the United Kingdom, Germany, and Australia. In the United States, the Interference Detection and Mitigation is being operated as a surveillance monitoring program (Brown & Edwards 2010, Weston et al. 2010). In the United Kingdom, the GNSS Availability, Accuracy, Reliability and Integrity Assessment for Timing and Navigation (GAADIAN) project has been performed for providing the availability, accuracy, reliability, and integrity of the Global Navigation Satellite System (GNSS) signals for time and navigation. In Germany, the GNSS Interference Monitoring System has been installed in an airport, which monitors the jamming signals for the GPS L1/L2 signals and the GLONASS L1 signal (Dunkel & Butsch 2000); and in Australia, CORSnet-NSW is being operated for the continuous monitoring of a GPS jamming signal (Janssen et al. 2010). These GPS jammer monitoring systems may guarantee the integrity by giving a warning

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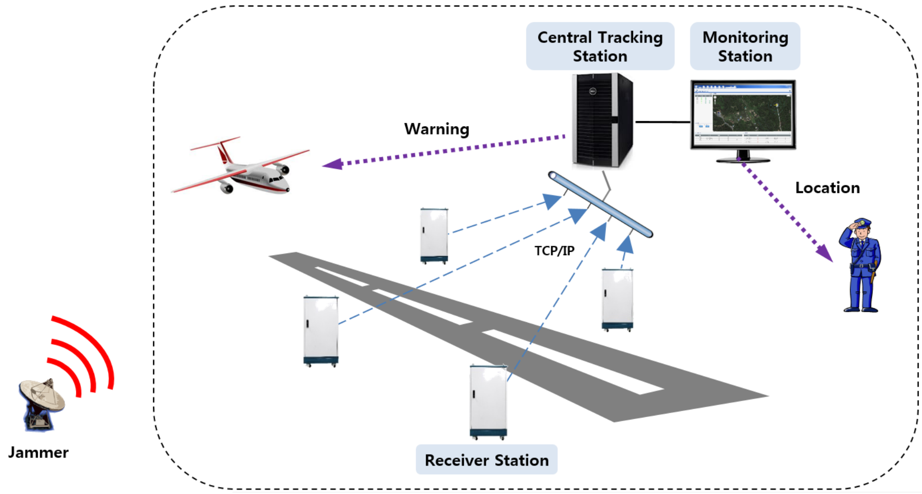

Fig. 1. Composition of GPS jammer localization system.

through detecting the occurrence of a jamming signal, but the continuity cannot be guaranteed if the jammer is not eliminated. Therefore, a system for estimating the location of a jammer is necessary for the prompt elimination of the jammer.

In this study, the characteristics of the developed GPS jammer localization system were summarized, and the results for the analysis of the jamming event occurred in April 2016 were described.

2. GPS JAMMER LOCALIZATION SYSTEM

2.1 Configuration and Characteristics

The GPS jammer localization system consists of receiver stations, a central tracking station, and a monitoring station as shown in Fig. 1, and the purpose of this system is to detect and localize the jammer within about 40 km of an airport.

The performance goal of this system summarized in Table 1. The localization performance is related with the distance to the jammer as well as the arrangement and number of receiver stations. Thus, it was assumed that the jammer is 10 km away from the center of receiver stations and four receiver stations are arranged with distance of 4 km. In addition, the minimum detectable power depends on the signal type, and thus that of the Direct Sequence Spread Spectrum (DSSS) signal was provided because the minimum detectable power of DSSS signal is the lowest value.

The signal types that can be detected by the developed system include Continuous Wave (CW), DSSS, and Swept CW. The CW signal is known to be the jamming signal mainly used by North Korea; the DSSS signal is the jamming

Table 1. Performance goal.

Item	Goal
Localization performance	50 m (@10 km, 4 km × 4 km)
Jammer detection time	Within 6 seconds
Minimum detectable power	JNR 0 dB
Detectable signal type	CW, DSSS, Swept CW

Table 2. Design parameters of receiver station.

		TDOA	AOA	RSSD	FDOA
Static	CW		O	O	
	DSSS	O			
	Swept CW		O	O	
Moving	CW		O	O	O
	DSSS	O			
	Swept CW		O	O	

signal used in the Hannover Airport case; and the Swept CW signal is the jamming signal used in the Newark Airport case. As summarized in Table 2, the algorithms used to detect and localize these signals are Time Difference of Arrival (TDOA), Angle of Arrival (AOA), and Received Signal Strength Difference (RSSD); and the algorithm used to estimate the speed was Frequency Difference of Arrival (FDOA).

To satisfy the performance goal, four receiver stations, one central tracking station, and one monitoring station were designed; and the functions and design parameters for each station are as follows.

The receiver station receives RF signals in the GPS L1 frequency band (1575.42 MHz) and converts them into Intermediate Frequency signals. Also, the receiver station transmits a certain amount of data to the central tracking station through TCP/IP every seconds. To perform the TDOA algorithm, time synchronization among the receiver stations is needed, and thus the time was synchronized using an optical network. As for the synchronization

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Table 3. Design parameters of a receiver station.

Contents	Parameter	Design value
Antenna	Array antenna	5 elements
RF F/E	RF bandwidth	2 MHz
	Quantization bits	14 bits
	Sampling frequency	62.5 MHz
	Phase mismatch	< 2 deg.
Data transmission S/W	Type	TCP/IP
	Data size	1.2 Mbyte
	Period	1 Hz
Digital board	CPU	600 MHz
	MCU	20 MHz
	TCP/IP	Max. 80 Mbps

Table 4. Design parameters of a central tracking station.

Contents	Parameter	Design value
CPU	Clock speed	2.40 GHz
	Cache	12 MB
Memory	-	32 GB
Ethernet	-	Broadcom 5716 (1333 Hz)
Hard disk	-	6 Gbps SAS 3.5"

Table 5. Design parameters of a monitoring station.

Contents	Parameter	Design value
CPU	Clock speed	3.10 GHz
	Cache	6 MB
Memory	-	4 GB DDR3 1600 MHz SDRAM
Ethernet	-	Dell wireless 1703 (802.11 b/g/n)
Hard disk	-	1TB SATA 3.0 Gb/s

Fig. 2. Array antenna.

Fig. 3. PCB of RF module.

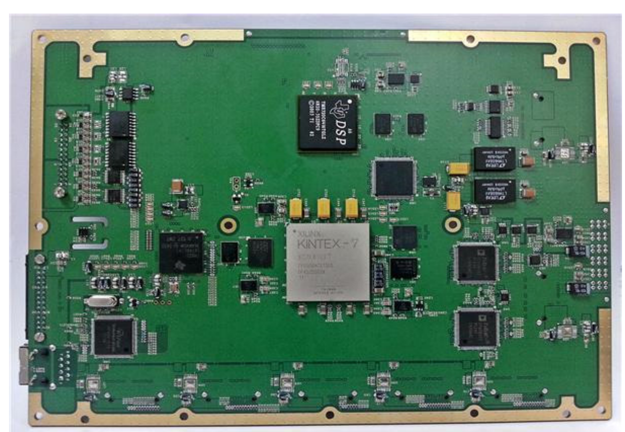

Fig. 4. PCB of a digital module.

method, one reference receiver station transmits a trigger signal, and the arrival time at the other three receiver stations were measured, which were then compensated at each receiver stations. The design parameters of the receiver station are summarized in Table 3.

The central tracking station stores the data collected from each receiver station, then detects and localizes the jammer by performing the localization algorithms. Also, it provides the results of the algorithms in real time through a web browser. For this purpose, the Linux server was adopted for central tracking station, and internally, it was separated as the data processing server and web server. The design parameters of the central tracking station are summarized in Table 4.

The monitoring station is a device for monitoring the status and results of the system by accessing a web server, and it consists of commercial PC and TV. The design parameters of the monitoring station are summarized in Table 5.

2.2 Development and Verification

The receiver station consists of a five-element array antenna that can receive signals in the GPS L1 band, H/W for signal processing, and a thermo-hygrostat rack for outdoor installation and operation. The figure of array antenna (ANTCOM) is given in Fig. 2 and the Printed Circuit Board (PCB) of five-channel RF module and the digital module are given in Figs. 3 and 4, respectively. The manufactured PCB of each module was installed in a thermo-hygrostat rack as shown in Fig. 5.

For the central tracking station, data processing server

Fig. 5. Rack with a thermo-hygrostat.

Fig. 6. Server of a central tracking station.

and web server have been installed in a rack that can be operated in an indoor environment as shown in Fig. 6 and implemented by using the Linux operation system. The central tracking station basically stores the data for past 15 days, and the data for some event situations are transmitted to and stored in Korea Aerospace Research Institute.

The monitoring station was implemented using a commercial Windows-based PC and a 55-inch TV as shown in Fig. 7. By accessing the web server using the commercial PC, the status of receiver stations and the jammer situation

Fig. 7. Monitoring station.

Fig. 8. Location of receiver stations in Incheon international airport.

can be monitored in real time. For this purpose, a web-based GUI program was also developed.

2.3 Installation

Each component of the aforementioned system was installed at Incheon International Airport in December 2014. The four receiver stations were installed on the roofs of the buildings, respectively, as shown in Fig. 8, and the distance between the receiver stations was 3~4 km.

One of the receiver station installed on the roof is given in Fig. 9a. The array antenna was installed at a height of 3 meters in combination with a radome. The receiver station was located next to the antenna, and was connected to the power and network provided by the airport. The central tracking station and the monitoring station were installed in

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(a) Antenna and receiver station (b) Central tracking station (c) Monitoring station

Fig. 9. Installation of the system.

Fig. 10. Strength of signals received in each RS on March 31th.

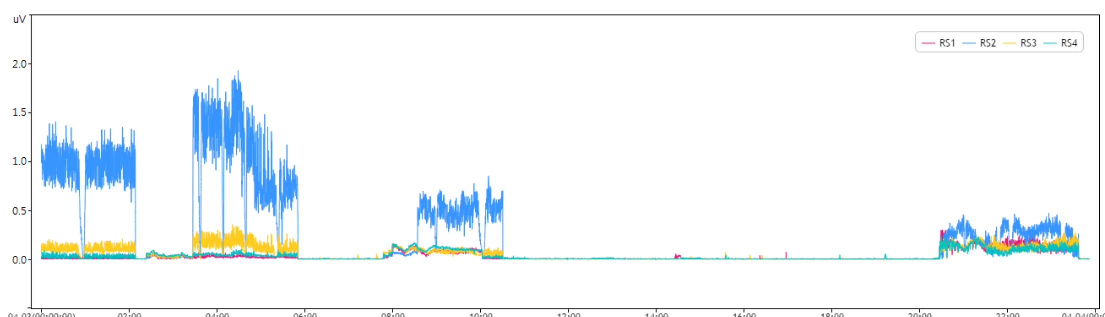
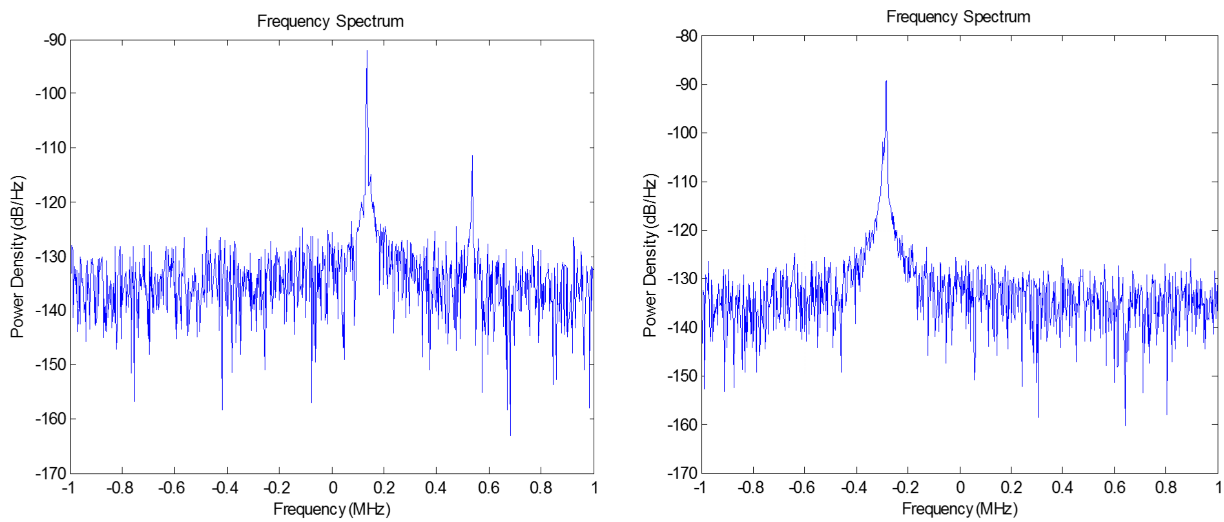


Fig. 11. Strength of signals received in each RS on April 3rd.

the indoor environment as shown in Figs. 9b and c, and they are monitored 24 hours a day by the person who is in charge of this system at the airport.

3. EVENTS ANALYSYS

In this section, the results of the analysis for the GPS jamming case occurred in April 2016 were given. The strength of the signals received at each receiver station on March 31 is shown in Fig. 10. From this result, it can be known that the jamming signal was firstly received at 19:35. The strength of the signals received on April 3 is shown in Fig. 11. From this results, it can also be known that the strongest signal during this event period was received at 04:30 and the amplitude and the power of it are 1.9 uV and 90.4 dBm, respectively. Compared with the strength of the signal received at receiver station 2, those of the signals received at the other stations were low as shown in Figs. 10 and 11, and it is thought to be the effect of geographic features in the propagation path. Due to this reason, the localization algorithm could not be operated, and only the signal characteristics and the direction finding results were analyzed.



(a) Signal received at 07:38:19 on April 1st

(b) Signal received at 07:38:20 on April 1st

Fig. 12. Frequency spectrum.

Table 6. Results of direction finding.

Date	Average (deg)	Standard deviation (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

Fig. 13. Strength of signals received in each RS on April 4th.

The frequency spectrum of the jamming signal is analyzed. The spectrum for the signal for 1 ms at 07:38:19 and 07:38:20 on April 1 are shown Figs. 12a and b. From this result, it can be known that the jamming signal has time-varying characteristics and bandwidth of it was about 50 kHz, and sometimes there were two jamming signals.

Using the signals received at receiver station 2, the azimuth angle was estimated by performing the direction finding algorithm through post-processing. The estimated azimuth angle for each day between April 1 and April 5 are given in Table 6. By expressing these results on a map, it can be found that the azimuth angle pointed towards the Gaeseong region as shown in Fig. 13.

4. CONCLUSIONS

In this study, the characteristics and installation results of a GPS jammer localization system was described, and the results of the analysis on the jamming case occurred in April 2016 were presented. The jamming signals showed narrowband time-varying characteristics and had the maximum strength of 1.9 uV (about 90.4 dBm) at Incheon International Airport. In addition, the azimuth angle of the jammer was estimated by using direction finding algorithm in post-processing and it indicated Gaeseong, North Korea. In the future, the cause of the low signal strengths at the receiver stations other than receiver station 2 will be analyzed through a sensitivity test.

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