Performance of TFDOA Convergence Algorithm to Improve the Efficiency of Jamming Signal Location Estimation

Chung-Sup Kim
Radio Research Division
ETRI
Daejeon, Republic of Korea
kcs@etri.re.kr

Hyuk-Je Kim
Radio Research Division
ETRI
Daejeon, Republic of Korea
hjkim@etri.re.kr

Sung-Woong Choi
Radio Research Division
ETRI
Daejeon, Republic of Korea
swchoi@etri.re.kr

Kwan-Woong Ryu
Radio Research Division
ETRI
Daejeon, Republic of Korea
kwryu0730@etri.re.kr

Jun-Seok Kim
Radio Research Division
ETRI
Daejeon, Republic of Korea
kjs1994@etri.re.kr

Abstract— Typically, arrival time difference (TDOA) and arrival frequency difference (FDOA) convergence algorithms combine two techniques to more accurately estimate the location of the source signal. TDOA is based on the time difference at which the signal reaches each receiver, and FDOA is based on the frequency difference of the signal. Combining of some this information can increase accuracy over using a single technique, but for adversarial jamming signals, it can also increase efficiently accuracy to other fusion methods

Here, TDOA and FDOA convergence algorithms with several fixed and one movement sensor mounted on the drone outperform other methods. Therefore, in the case of GPS jamming, it is recommended to use drone-type sensors and ground sensors based on algorithms that are resistant to interference

Keywords—TDOA, FDOA, convergence algorithm, jamming signal, Geo-location method

I. Introduction

Interference source position estimation is a classic problem in radars and sonar. Recently, interest in this research has risen again, driven mainly by emergency positioning capabilities applied to wireless services and sensor network applications.

In general, in urban areas, AOA (Angle Of Arrival)-based systems have difficulty estimating locations due to problems such as multi-paths caused by buildings and structures.

Therefore, the TDOA system based on the sensor network is more resistant to interference and can be used as a substitute for the AOA system in urban areas, but the accuracy of performance degradation caused by the Geometry layout structure and illegal signals with low BW (information content) were reduced, so they were used in parallel with the AOA system or fused with a separate additional RSS (Received Signal Strength), but it is difficult to use due to inaccuracies in RSS due to signal attenuation conditions.

This paper focuses on various methods, such as TDOA position estimation for fixed interference sources in adversarial environments, and TDOA and FDOA fusion position estimation methods for over-moving sources.

TDOA and FDOA indicate the difference in arrival time and Doppler frequency between the received signals measured by the two receivers. The signal source location information is obtained by estimating the intersection of the position line corresponding to each measurement. This signal source location estimation process consists of measuring TDOA and FDOA information by considering noise and channel conditions in the original received signal, and using the measured values to estimate the signal source location.

The accuracy of the estimation of the location of the interference source is highly sensitive to the receiver location and the speed of the sensor.

This paper shows to perform an analysis and present a solution to find an interference source using TDOA and FDOA measurements when the receiver location is located outside a specific boundary that sensors cannot reach.

The proposed solution is a TFDOA fusion position estimation method including one UAV sensor with high movement speed and is intended to be superior to other fusion methods

II. Methods

A. Test condition

In the case of the TFDOA Geo-location model proposed in this paper, the following equation 1 was applied to one UAV and a fixed ground station sensor.

$$S_1(x_e, y_e) = \tau_{12} = \frac{R_1 - R_2}{c},$$
$$S_2(x_e, y_e, f_e) = v_{12} = \frac{f_e}{c}\frac{d}{dt}(R_1 - R_2) \qquad (1)$$

The upper part of Equation 1 represents the TDOA-related measurement method, the lower part represents the FDOA-related method, and an appropriate time variance value and frequency error rate were used for simulation similar to the actual environment.

Figure 1 below shows the environmental structure of performing the fusion-type location estimation algorithm to be proposed.

The interference source transmission point is located on a red dotted line that is physically difficult to access and is a hostile interference source, so it uses flights such as UAV and exchanges data with sensor countries on the ground to prove that the TFDOA fusion algorithm structure is efficient compared to other location estimation algorithm results.

Of course, the location estimation algorithm has a significant performance impact on the geometric arrangement between the interference sources and the sensors, but in the case of an adversarial interference source environment as shown in Figure 1, a TFDOA fusion algorithm using UAVs and ground sensor stations placed on almost the same line is considered efficient

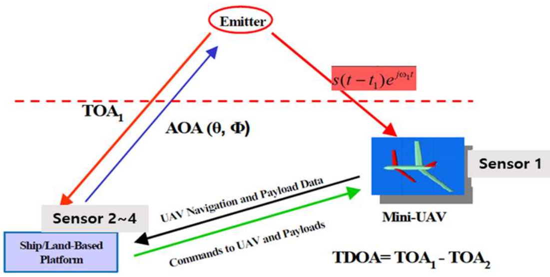

Fig. 1. Block Diagram of algorithm proposed

Figure 2 is a picture of the detailed test conditions used in the simulation. For convenience, the location of the interference source is located at the origin and the altitude between the sensors and the interference source is the same. The movement sensor performs the fusion algorithm, etc., by measuring 40 times continuously from the initial starting point to the final point at intervals of 250 m

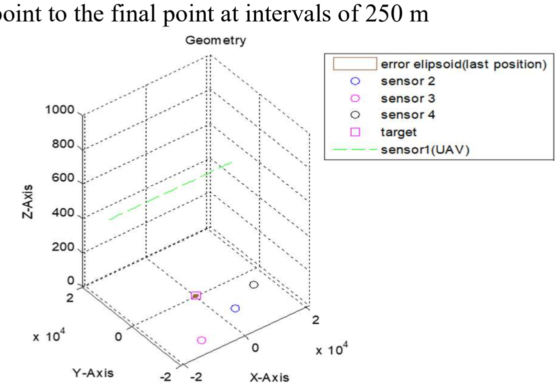

Fig. 2. Block Diagram of algorithm proposed

Table 1 below shows the location information of sensors and interference sources, and the algorithm used for location estimation in various ways is a Non-linear Least Square (NLS) algorithm, and various sensor counts and algorithm combinations were used.

Table 1. Block Diagram of algorithm proposed

	Sensor location	Variance	Geo-location algorithm
Sensor 1(UAV)	[-20000:250:end, 10000, 500] velocity = 300m/s	AOA= 1°	AOA & FDOA
Sensor 2	[5000, -10000,0]	TDOA= 100ns	AOA & TDOA
Sensor 3	[-10000, -15000,0]	FDOA=1Hz	FDOA only
Sensor 4	[15000, -5000,0]		TDOA & FDOA

III. LS-BASED TDOA/FDOA POSITION ESTIMATION

A. *Result of algorithm proposed*

Figure 3 is the result of testing the ground station sensor 1 and the NLS-TFDOA fusion algorithm by varying the speed of the UAV sensor to 30m/s and 300m/s.

As the resolution of the frequency shift is improved when the UAV speed is high, the UAV test results at 300m/s were excellent, and as will be explained later, the UAV speed affects the performance more than the number and performance correlation of ground station sensors, indicating that the performance of the TFDOA fusion algorithm can be estimated with only the minimum number of sensors.

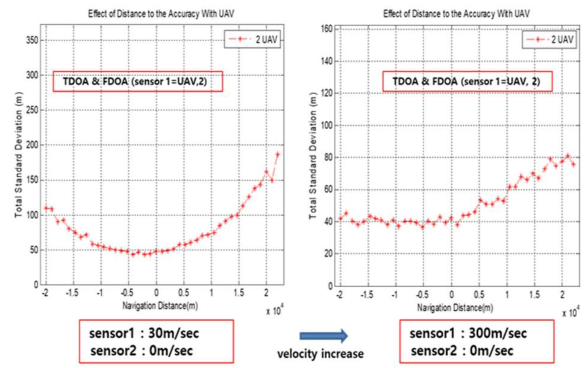

Fig. 3. Performance of alogrithm porposed compared to conventional spatial filter based on estimated interference information in a situation of interference and signals

The results of Figure 4 are the simulation results of the FDOA, AOA & TDOA, AOA & FDOA, and TDOA/FDOA fusion algorithms using all the sensors in Table 1. Although there are differences in detailed results depending on the location of the UAV sensor, the proposed TFDOA fusion algorithm shows the best performance in environments where the interference source exists in a location where our sensors cannot be close (such as across the human line) and cannot take a geometric shape position to embrace the interference source.

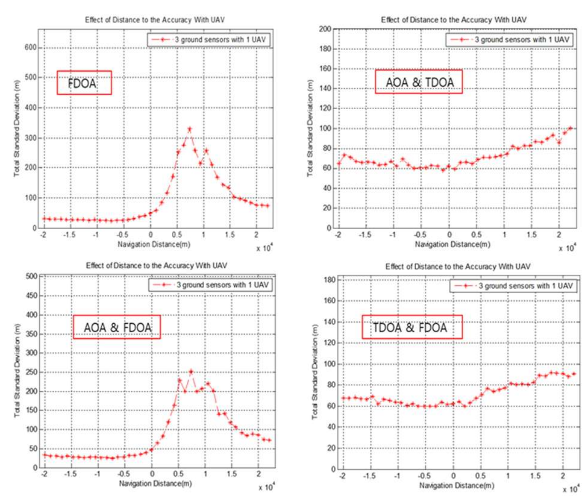

Fig. 4. Performance of alogrithm porposed compared to conventional spatial filter based on estimated interference information in a situation of interference and signals

IV. Conclusion

The TFDOA fusion method performs better than various other methods in situations where the hostile interference source is located outside with the branch line as the boundary and the signal source must be able to estimate the location as quickly as possible.

In addition, the results of varying the speed of the UAV sensor were also presented, confirming that the faster the sensor, the better the performance. In the future, in order to increase the accuracy of estimating the location of the moving interference source, we intend to study a new method of acquiring the results of the TFDOA fusion location estimation algorithm faster and estimating the location of the moving interference source based on the obtained results.

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